VOL. 37, NO. 3. JULY 1960

TROPICAL AGRICULTURE

THE JOURNAL OF THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

CONTENTS

		PAGE
V. D. WICKIZER	*Some Aspects of Agricultural Development in the Tropics*	163
H. HIRST	*Land Use Projects in Cyprus*	177
T. J. LANSBURY	*A Review of Some Limiting Factors in the Nutrition of Cattle on the Accra Plains, Ghana*	185
K. W. HARKER	*Defaecating Habits of a Herd of Zebu Cattle*	193
A. K. AUCKLAND	*Soya Beans in a Mechanized Farming System in Tanganyika*	201
K. SHEPHERD	*Seed Fertility of 'Gros Michel' Bananas*	211
D. H. PARISH and S. M. FEILLAFÉ	*A Comparison of Urea with Ammonium Sulphate as a Nitrogen Source for Sugar-cane*	223
B. WALKER	*The Effect of Soil Type and Soil Moisture Content on Growth of Sugar-cane in the East Coast Area of Demerara*	227
P. HOLLIDAY	*A Spraying and Harvesting Trial in Trinidad against Cocoa Pod Diseases*	235
BOOK REVIEWS		243
RECENT PUBLICATIONS		254

PRICE: 10s. net post free

(£2 per annum for four quarterly numbers)

Published on behalf of the College by

BUTTERWORTHS

LONDON · TORONTO · SYDNEY · WELLINGTON · DURBAN

1960

COMMONWEALTH MYCOLOGICAL INSTITUTE
14 JUL 1960

Noxious insects, fungus diseases, weeds, vermin

have through the centuries incessantly continued to inflict devastating damage to agricultural crops, to reduce harvest yields, to destroy foods and materials, and to endanger the health and lives of mankind and animals; all too often peoples perished and cultures were exterminated due to plagues of pests, and until recent times man was powerless against these parasites.

Crop protection as a factor for increasing and safeguarding yields assists the farmer to reap those harvests which he should realise from the use of high-quality seed, application of cultivation practices and fertilizers. Crop protection and pest control are essential for guaranteeing supplies of food sufficient to satisfy the needs of people throughout the world; today these measures constitute a task of national economy and have attained world-wide, international importance, but for the individual farmer they are a top-ranking problem of farm management.

The research workers of Farbenfabriken Bayer have rendered meritorious service through the development of chemical products for crop protection and pest control – highly effective and fully reliable products, valued throughout the world, that spare people and countries economic damage, distress and suffering.

Cupravit – copper spray
Dipterex, Gusathion, Chlorthion – new type insecticides
Folidol, E 605 – methyl parathion, ethyl parathion
Hedonal – weedkiller
Metasystox, Systox – systemic insecticides
Pomarsol – TMTD spray
Tugon – fly killer
Seed dressings for all uses

BAYER

FARBENFABRIKEN BAYER AKTIENGESELLSCHAFT · LEVERKUSEN
GERMANY

Agencies in all countries of the world

Some Aspects of Agricultural Development in the Tropics

V. D. Wickizer
Food Research Institute, Stanford University, California

LABOUR SUPPLIES AND THE LABOUR PROBLEM

Changes which have occurred in recent years in tropical crop production, and are still occurring, all result in higher overall costs. Since labour is the principal item of expense in the production of most tropical export crops, costs are greatly influenced not only by the character of the labour supply but by sundry economic and social pressures, especially evident since 1945. Technological advances have not been sufficiently rapid to compensate for higher-priced labour nor does world demand seem to promise an indefinite passing-on of higher production costs to ultimate consumers.

Labour, the human ingredient in the production of wealth, must be considered both as to quantity (supplies) and quality (skills). Here special attention is given to labour in tropical Africa, where some foresee a future development of crops for export comparable to that which took place in south-east Asia during 1840–1940.

Present limitations on labour supplies

In one sense labour for tropical agriculture is plentiful. Millions of Asiatic, African and Latin American farm workers are, in effect, underemployed. But it is no longer easy to secure contract labour for several years or even seasonal (or migrant) labour for a few months. For this reason alone some foresee a dim future for the plantation system of production, the life-blood of which has long been a plentiful supply of cheap labour (e.g. Lewis, 1950, p 64).

The old system of importing contract labour for a term of years was often abused. In order to protect their nationals the leading exporters of surplus labour have instituted legal restrictions and set up machinery for clearing contracts and controlling the flow of migratory labour. The principal countries employing plantation labour have introduced laws designed to assure suitable working conditions and wage rates. But in less well developed areas of the tropics, such as Africa, conditions are little changed from the past, although the cost of traditional seasonal labour has gone up.

With plantation operations so heavily dependent upon the extent and character of the available labour supply, there is every incentive to reduce the importance of this hefty element in overall costs. But adjustments secured by greater mechanization, for example, run squarely into a host of problems other than those of a strictly economic nature.

Local or regional labour shortages and competition for labour have increased; the lure of urban employment has been as much responsible for

the change as alternative opportunities in agriculture. Meanwhile, social legislation governing wages, working conditions, housing and medical care, have resulted in raised standards and higher costs. Labour union activities have played a part in this development in a number of countries.

Conditions under which plantation labour is available

Even in areas of dense population, the recruiting of a labour supply has long been a problem for many plantations. Ceylon imports the greater part of its estate labour from southern India, where there is a surplus; and Sumatra has drawn upon Java. India and China have constituted a labour pool for Malaya. In Africa, migratory labour plays an important role in commercial agriculture. Commonly the native has his own land to work, and is not interested in estate employment except at times when his crops have failed, when there is a regional surplus of farm help, or when he has a need for money for some specific purpose.

In Africa there is a continuous movement of workers to and from the reserves. Some idea of the magnitude of this movement is suggested by the situation in Kenya. Of approximately 350 000 adult male African workers in employment outside the reserves, more than half are considered of the migrant or 'target' type '. . . workers who have left the reserves for a specific purpose—for example, to earn sufficient money to pay tax, replenish a wardrobe or acquire a wife or, perhaps, merely for a change of environment—and return to the reserves once that purpose has been achieved' (Colony and Protectorate of Kenya, 1954, p 13). This temporary employment of such a large proportion of the African male workers outside the reserves necessarily means for employers a high rate of labour turnover with its attendant effect on labour costs. Furthermore, the labourer does not acquire skills rapidly, if at all, and costs of production cannot be reduced by an increase in labour efficiency.

In contrast with the migrant labour system common in Africa, upon which plantation enterprises must largely depend, the estates of south eastern Asia enjoy a far higher degree of stability even though migrant labour is important in some areas. The older estates of Indonesia, for example, are frequently served by successive generations of families located on the estate or living in nearby villages. In Africa, even where minima are established, the wage level is so low that it provides little more than enough to support the worker himself. Families must stay behind in the villages in order to support themselves.

The character and composition of the plantation labour force varies widely, depending upon location, nature of crop produced, methods of recruitment and payment, hours of work, and so on. The International Labour Office has concerned itself with the conditions of life and work on plantations. In a report published a few years ago it describes conditions of work, living conditions, labour relations and inspection as revealed by its survey. The substance of its comments is that there is much room for improvement, but in general the plantation worker is better off than other hired agricultural workers, especially those employed in native agriculture, even though not as favourably situated as industrial workers in the same region or country (*International Labour Review*, 1950, p 296).

Qualifications and prospects of tropical labour

Perhaps more important than the size of available labour pools are the qualifications of labour for the varied tasks that must be performed. Despite educational programmes, progress has been slow in developing needed skills on the part of indigenous populations. New techniques in the field and factory have created a demand for better-trained personnel, but this demand is not being fully met. One of the urgent problems, especially of plantation management, is to qualify labour for new tasks created by advances in agricultural techniques.

Several factors contribute to the inefficiency or ineffectiveness of tropical labour, the most important being poor health and ignorance. Tropical diseases and poor diets may leave a worker physically unable to perform effectively. Lack of education, superstitious beliefs, and limited contact with the world outside his village, make many uncertain candidates for employment.

Some observers take a dim view of the prospects of training any large number of the tropical labour force in badly-needed skills; others are more optimistic. Extensive under-employment caused by the seasonal nature of crop production would presumably be accentuated by improvements in farming methods. Development of small-scale village industries, as in parts of China and India, might provide employment for farm labour during off-seasons.

The number of days a man works, and the hours per day, are largely governed in agriculture by natural conditions such as location, climate, length of day, nature of the soil, and by custom. But the type of farming involved, the size of the farm, and the crop or crops grown are also controlling factors. In most one-crop operations there is no way to avoid periods of idleness or to smooth out peak demands for labour during planting or harvesting, even when the crop grown is perennial.

Few agricultural workers in the humid tropics put in an eight-hour day; more commonly four or five hours constitute a day's work. Under the circumstances the labour pool for a plantation is necessarily larger than otherwise it would be in order to accomplish the tasks at hand. This complicates training and supervision, and results in a low level of productivity. When the worker lives on or near the plantation in more or less permanent status, and perhaps has his own small plot of land for growing foodstuffs, his free time need not be wasted. But for imported temporary (' bachelor ') labour, used for a relatively brief period during the day, no useful occupation is presented in off-hours.

In East Africa the sisal or other plantation, extending over thousands of acres, with little supervision, is prone to poor efficiency.

> The labourers start work at seven o'clock . . . and are almost always back in camp with their tasks finished by midday. A proof of the small amount of work done is to be found in the standard task; this is supposed to represent a day's work for the average man, but in practice, an exceptional worker . . . will do two, and not infrequently three, normal tasks a day . . . without any great effort . . . even worse is the high degree of absenteeism . . . Consequently, the average working week for the plantation is probably under rather than over twenty-five hours (MATHESON and BOVILL, 1950, p 33).

The statement that an ' exceptional worker ' may do two or three times a normal task without great effort rather contradicts the commonly expressed

belief that the peasant farmer or labourer will not respond rationally to financial incentives. It is true that less rather than more effort has frequently been the reaction to greater income, whatever its form. To generalize from such experiences, however, is to fail to make certain distinctions as to motivating forces that govern the primitive agriculturist from one time or one situation to another. The native labour pool of any tropical area is never completely homogeneous; and responses to monetary inducements vary under different circumstances.

In African experience the farm worker may seek a wage-paying job merely as a temporary proposition in order to earn a little extra money for some specific purpose, or he may be induced to leave his tribe for more permanent employment. In the former case an increase in wages permits a faster accumulation of savings. Then workers 'see no further point in working and either slacken off or try to leave. What is taken to be a lack of logic, or as a sign of indifference or laziness, is in fact the outward expression of a perfectly valid piece of reasoning' (DE BRIEY, 1955, p 106). In the latter case, experience has demonstrated that the African worker's productivity may be increased by financial incentives, even though the problem of providing adequate substitutes for familiar tribal surroundings has apparently not been solved.

Some of the problems involved

Certainly experience has demonstrated that all too frequently tropical man is unwilling to exert extra energies solely for financial reward once his simple needs have been met. Agricultural officers recount experiences by the score of attempts made to increase productivity by the introduction of demonstrably better planting materials and methods, only to find that output remained the same while land use or labour input declined.

It is often contended that new and additional wants on the part of the tropical farmer must be created in order to provide incentives to work longer, harder and be receptive to better methods—all to the end of increasing money income and purchasing power. This task has sometimes seemed hopeless, or at best a prolonged process. Yet rapid changes have occurred since 1945. Men who saw service and escaped their restricted environment for the first time in their lives returned to their villages restless, filled with new ideas and wants, all of which were reflected in the family and community.

In the course of economic development of any country it is expected that people will leave the land and be absorbed in other sectors of the economy —in manufacturing, trade or transportation. This does not occur rapidly at present with the generally low level of skills possessed by the typical tropical worker. And even where and if appropriate skills are developed a host of new problems arises. The family, tribal or village responsibilities for employment, health, education and old age are transferred to the state.

The urgent need for additional education and training of the typical tropical worker is everywhere recognized. Lack of funds and qualified teachers has retarded public education; and lack of incentive, with an unstable and temporary labour force, has kept many employers from any effort more than the minimum of on-job training. It has been demonstrated that many tropical labourers can be taught skills that greatly increase their

efficiency. There is nothing hopeless about the outlook for creating a competent labour force in under developed countries. But there are few short-cuts in the long slow process of education, and results may not appear for a generation.

Part of the process of educating the tropical worker in agriculture must be government-sponsored extension work. The dissemination of knowledge about crops and their requirements, and about the best cultural techniques of production under the given environmental circumstances, presupposes that experiments have been made that demonstrate the merits of the procedures advocated. Research which only governments are in a position to finance and conduct is a pre-requisite to any broad extension programme. All this costs money and calls for highly qualified personnel. When governments of underdeveloped countries are responsible not only for the general education of the population but for specific training in agriculture, it is to be expected that the item ' education ' will (or should) loom large in the national budget.

In addition to its role in providing a manpower pool, the tropical labour force also influences the pace of economic development in other ways. Resistance to changes that disturb existing patterns of work or social arrangements, however based, protract and complicate efforts at progress. Fear, suspicion or simply colossal ignorance, are motivating factors which can be eradicated only by broad educational efforts. Proper understanding of changes proposed for the betterment of the labourer and his economy must be based upon the removal of doubts and fear of exploitation. Educated or not, the tropical worker is not quick to forget some of the evils of the past whether these originated with the now unpopular foreigner or with his own political leaders.

CAPITAL NEEDS FOR LABOUR ECONOMY

Capital requirements of tropical crop production vary enormously depending upon such things as cost of land, water supplies, utilities, processing equipment and accommodation for labour. Sometimes expensive irrigation or flood control schemes are necessary to make available land usable. The land must be cleared, roads and other forms of communication provided. If the crop requires processing near the place of production, capital requirements for equipment are sometimes so heavy that only the plantation company can afford the outlay needed. Local capital resources are usually limited or local capitalists are unwilling to accept the risks involved, and outsiders must be called upon. A crucial problem today is the provision in many underdeveloped countries of a favourable political ' climate ' for attracting needed local as well as outside capital.

For crops susceptible of mechanized growing and harvesting, capital needs are further increased. Because of existing pressures on the structure of production, especially from changing labour costs, efforts to mechanize have been intensified. In the process of experimenting much is being learned about the potentialities and limitations of mechanization as applied to crops produced in the tropics. Also the financing of much needed research designed to improve cultural techniques, control diseases and

upgrade the quality of processed products, is high on the list of capital requirements for tropical crop production.

Labour applied to appropriate land makes it productive and useful in supplying man's wants, but capital may substitute for labour in some respects and also increase output and raise living levels. In some cases the substitution may not be made properly and the results obtained may be uneconomic, but such instances are rare. The capital needs of tropical crop production are many and varied; basic public works, for example, may be a pre-requisite to agricultural development, but projects which require large sums of capital, such as the provision of communications and flood control, although primarily in the interest of agriculture, may be not exclusively so. Such needs are fundamental to the development of any underdeveloped economy, whether or not predominantly agricultural. The considerations involved are technical or engineering, political and financial.

Today there is every incentive for agricultural management to seek ways and means of injecting more capital into the production complex in the form of labour-saving devices. The large corporate agricultural undertakings may have relatively easy access to the capital markets, but it does not follow that the array of mechanical contrivances they assemble will assure successful pursuit of cropping schemes. Even backed by the resources of the British government, the famous post-1945 groundnut scheme in East Africa was an admitted failure. If such fiascos can occur under the auspices of experts, the chances of the small peasant farmer seem dim indeed, even if he were to command the necessary capital resources.

A vast government-sponsored agricultural scheme on the one hand, and one within the possible scope of smallholders if their resources are pooled, on the other, are quite different. Possibilities of mechanizing native agriculture exist just as in plantation agriculture, but on a different scale. It is well to establish at this juncture a somewhat clearer concept of what is meant by agricultural mechanization.

The scope of mechanization

In the voluminous discussion of recent years it is quite clear that mechanization of agriculture means different things to different people—from the substitution of a steel blade for an iron or wooden one to the installation of power-driven machinery either for work in the field or for pumping water or grinding grain. Mechanization takes on still other meanings in the tropics: special conditions there make inapplicable certain forms of farm mechanization which are quite appropriate in temperate zone areas.

The most common concept of mechanization is the introduction of mechanical power to various phases of agricultural production. It is the substitution, as a power source, of internal combustion engines and electric motors for human and animal labour. The application of improved tools and implements may also be considered mechanization. Certainly tools and power source go together. Mechanical power introductions are usually accompanied by improved tools—indeed they are necessary for effective application of power. A distinction of importance that must be made is between improved power applications to the land itself and power applications to the various services necessary to make use of the land profitable—

services including such things as water pumping for irrigation and milling of harvested crops. Some writers consider road building and truck transportation part of the mechanization process. In broad terms, all devices that improve present practices and results may be construed as forms of mechanization.

In appraising the need and the ability of less-developed countries to adopt mechanization an FAO report states: ' It is not unusual to conclude that even though ploughing, cultivation, seeding and harvesting can profitably be undertaken by hand and animal power, water raising, threshing, draining and grinding should be mechanized by installing engines or electric motors on individual farms or communally '. But the report also cautions: ' In considering improvements in farming practices the tool or machine and the power that propels it must be kept separate if confused planning is to be avoided ' (United Nations, 1944, pp 3, 5).

Mason Vaugh (1954, p 15), in another FAO report, also places emphasis on mechanizing of what he terms ' barnyard operations ' but seems to consider the introduction of better tools and implements a most promising forward step.

> To say that we are opposed to mechanization of field operations at this stage is not to accept the present methods. The effectiveness of the presently available human and animal power can be increased many times by the use of better tools and implements, tools and implements which can be introduced into the present pattern of cultivation without drastic changes in social organization and with a minimum investment of capital and a minimum demand on scarce metals supplied.

Vaugh believes that reduction in drudgery and increase in food, feed and fibre production can be most rapidly and effectively accomplished ' at this stage by the widespread increase in the use of improved implements and tools . . [and] by concentration of efforts towards mechanization . . . of the barnyard operations, those operations done at the farm or village site rather than in the field '. He takes a rather dim view of mechanization possibilities of field operations under conditions existing in the densely populated areas of the Far East. At the same time he considers the primary objective of mechanization one of ' increasing the area which one person can control or use effectively ' (Vaugh, 1954, p 11).

A summary of reports presented at an international conference on rural development in tropical areas a few years ago stated that ' there is still uncertainty of the ecological or economic advantages of mechanized cultivation in the tropics ', but also observed that ' . . . the removal of drudgery is most important and here the mechanical power introduced into the economy may perhaps most profitably be applied first to milling, water pumping, road building and transport, etc., and to the actual cultivation of the soil last ' (Beckett, 1953, p 301). This emphasis on so-called ' barnyard ', as distinct from field, operations seems to reflect views influenced by conditions in tropical Asia. There population is generally dense, holdings are typically small, and corrections present immense difficulties. At best prospects for change and improvement are long-run.

Agricultural mechanization in practice

The view that ' in the crowded countries of the East, the total of human happiness will be greater if the land continues to be divided into small

holdings than if it is combined into large units with the accompanying problems of social organization ' (VAUGH, 1954, p 12) seems not to be general, but reflects the peasants' desire for land ownership and the obstacles to consolidation of holdings regardless of title-holder. The preference or priority given to the mechanization of ' barnyard ' operations is understandable in these circumstances. Yet in the same countries mechanization of field operations has ample scope and promise, e.g. tea plucking in the gardens of India. Labour shortages during 1939–45 and rising labour costs stimulated a new interest in mechanical plucking not only in India but in all the principal tea-growing countries (WICKIZER, 1951, p 436).

Perhaps it is only in the mostly densely populated areas of tropical Asia that possibilities for the mechanization of field operations are not viewed so favourably. The mechanization of rice culture has received much attention in such countries as Ceylon, Malaya and the Philippines. It has been demonstrated that ploughing, harrowing, transplanting and harvesting of lowland rice can be done successfully by mechanical power.

> Particularly noteworthy developments have taken place in the mechanization of paddy cultivation and harvesting. Large-scale operations have been in progress in British Guiana for more than 10 years, and extensive pilot schemes have been initiated elsewhere, including Tanganyika, Sierra Leone, and Nigeria. Experiments in Malaya have gone far to establish the feasibility of mechanical methods of cultivation under local conditions and particular attention is now being paid to harvesting and threshing. In Surinam two-tractor ' family ' farms have been planned on a basis of 72 hectares, of which 12 to 24 hectares would be in grass. Special attention is being given in Surinam, Malaya, Nigeria and elsewhere to the problems of clearing swamp forest and mangroves; and present indications do not, in general, appear to favour purely mechanical methods—whether considered on an economic or a physical basis (MAYNE, 1954, p 182).

In Ceylon rapid development of tractor tillage has been limited by the unfavourable terrain or incomplete clearance of much of the new paddy land being opened up, seasonal use of machines, and the absence of adequate service, spares, repair facilities and trained personnel. There are at least 600 agricultural tractors in operation in the country, their effectiveness has been demonstrated, ' but whether all of them are being put to the best possible use is difficult to state ' (*Tropical Agriculturist*, 1954, pp 2–4). For a number of years the Department of Agriculture in Malaya has conducted investigations into the mechanical cultivation and harvesting of wet *padi*, the results of which are reported periodically in *The Malayan Agricultural Journal*. Mechanization is considered both possible and practicable in the Philippines. ' However, maximum economy in the mechanized methods of lowland rice farming would require the building of bigger-sized paddies of at least one-fourth hectare, to lessen loss of time in turning or maneuvering around the field ' (CAPISTRANO, 1953, p 96). It is estimated that a man using buffalo can plough one hectare in about seven days but with a machine can do the job in less than half a day (CAPISTRANO, 1953, p 85). In other parts of the Far East experiments in mechanization are being conducted with tree crops as well as field crops. Even in coconut culture there to be possibilities for mechanization which have not yet been investigated or demonstrated by experiment—in land clearing, planting, maintenance and harvesting (LEFORT, 1956, pp 21–22, 29).

In the Western Hemisphere mechanization of field operations has received much attention not only in temperate zone countries such as the United

States but also in tropical America. A common feature of the policy recommendations of most of the official investigations into the sugar industry of the West Indies, for example, ' has been emphasis on the need for further mechanization in the agricultural phase of the industry ' (MATTHEWS, 1951, p 52). The fullest possible mechanization of the industry is advocated as a means of raising productivity and living levels.

A British Colonial Office report on mechanization of native agriculture in Africa deals primarily with the possible use of tractors, although it concedes that other forms of mechanization (' barnyard ') could make labour effective during busy seasons. It found many obstacles to efficient mechanical cultivation and generally displayed a lack of enthusiasm for this type of mechanization. The report observed that on economic grounds ' the substitution of tractors, tractor fuel, other equipment and materials, trained drivers, mechanics, field supervisors and European staff for ordinary native farm labour would be substitution of costly for cheap factors of production '. It further stated that ' with high current costs and greater capital requirements mechanical cultivation will thus be economic only to certain limited extents. . . . further use of tractors in weeding, harvesting and threshing would usually cost too much as compared with any net increase in production it might bring about . . .' (Colonial Office, 1950, pp 1–2). (The current and potential contribution of tractors and related equipment to tropical agriculture has recently been given detailed, practical consideration in a book-length treatment of mechanization. See BATES, 1957, especially Part II.)

Difficulties in using agricultural machinery under the widely varying soil and climatic conditions found in the tropics have frequently been pointed out, but an equally important problem is:

> . . . the shortage of really first class, trained and experienced staff at all levels . . . mechanization is usually very costly owing to high rates of depreciation, breakage and to the expense of repairs . . . 25 to 30 per cent of the tractors in any scheme are likely to be out of action at any one time owing to breakdown or shortage of spare parts . . . (MAYNE, 1954, pp 179–81).

Agricultural tractors in the tropics today are used primarily for land-clearing and preparation of the soil for planting. Less urgent operations are frequently more economically carried on by human or animal labour.

Although much of the experimental work with mechanization has emphasized field operations, there is scope for improvement in factory equipment and procedures in connection with the processing of tropical export crops. This is not nearly such a pressing problem, however, since necessary processing is being carried out even though it may not always be efficient. The greatest scope for advances in preparing tropical raw materials for marketing lies in the peasant sector of the agricultural economy. The substitution of power for hand labour and modern equipment for crude extraction mills will show maximum results. Mechanization of this type falls into the category of ' barnyard ' operations, referred to earlier. Its importance varies with the crop concerned, but for a number of plantation crops processing skill is a measure of relative advantage of one type of agriculture over another.

RESEARCH NEEDS AND POTENTIALS

As important as capital itself in economic development is the broad programme of research that must precede activities designed to make intelligent and effective use of funds that may become available. Limited local capital resources of the underdeveloped economy may be supplemented by outside sources, but to secure the knowledge that results from research is more difficult. Everywhere in tropical countries there is a crying need for reliable information not only upon the basic environmental factors in agricultural production, but upon ways and means of utilizing to best advantage the various procedures and techniques that may be available and adaptable to the particular conditions existing at the time.

Research is indicated as a pre-requisite to improvements in cultural techniques, both from the standpoint of fundamental knowledge itself and from that of applying such knowledge to situations at hand through education and extension work. And, of course, scientific investigation must continue in such matters as soil analysis, plant-breeding, disease and pest control, and fertilizing practices. Some observers, in fact, feel that too much emphasis is being given to such institutional matters as fragmentation, size of farming units and marketing arrangements; and too little to other means of increasing efficiency, e.g. water supplies, seed farms for improved seed, fertilizers and agricultural extension services. They question whether increase in farm size and the introduction of machinery are wise policies, especially for over-populated areas.

One writer states his views on the appropriate approach to a development problem as follows:

> The secret of rapid agricultural progress in the underdeveloped countries is to be found much more in agricultural extension, in fertilizers, in new seeds, in pesticides and in water supplies than in altering the size of the farm, in introducing machinery or in getting rid of middlemen in the marketing process (Lewis, 1955, p 136).

Few will question the importance of these factors: all are based more upon research than upon modifications in the structural aspects of tropical agriculture. The author gives priority to agricultural extension, considering it the most productive investment that can be made in poorer agricultural economies, and observes that agricultural research in the tropics has been concentrated on commercial export crops, but that there is a great need for research on crops grown for local consumption (Lewis, 1955, pp 187–88). The past emphasis upon commercial export crops is understandable, especially in view of the dominant role played by plantations in their production. Future growth in knowledge of other tropical crops will most likely come from government-sponsored efforts rather than from individual initiative.

The great strides that have been made in developing appropriate fertilizers, better planting materials and pesticides are largely the result of plantation-sponsored research, experimentation and investigation. Although such results commonly become the property of all interested parties, the cost element is frequently a deterrent for the small farmer. Generally the peasant grower must be subsidized in one way or another by government if he is to have access to the new scientific developments. And equally important, he must be convinced of their value and taught how to capitalize upon such

discoveries. They must be applied to his own situation, with modifications and adaptations as necessary. Here, the role of the extension worker is vital: he need not (and probably should not) be a university graduate, but rather a locally-accepted individual with farm experience and training in new techniques so that he may transmit the knowledge of methods that have demonstrable worth.

A common observation of experts in the field of tropical agriculture is that serious mistakes have been made in attempting to transfer the techniques of temperate-zone agriculture to the tropics without adequate adaptation. Despite such criticism and warnings, it has only been in relatively recent years that much heed has been paid to such advice. A good example is the former almost universal practice of clean weeding on any well-regulated plantation. The absence of clean weeding in peasant agriculture was once considered merely another sign of laziness on the part of the cultivator. However, during the depression years of the early 1930s when it was imperative to reduce costs, weeding on plantations was curtailed with surprisingly beneficial results. Today, for many crops and in many areas, all except the largest weeds are allowed to grow, hold the soil, and when killed finally mulched into the ground instead of being removed. It is said that ' proper methods ' of weed control may increase yields in the tropics and sub-tropics by ' 100 per cent or more ' (Ashby and Pfeiffer, 1956, p 227). With the high cost of labour and hand weeding, the use of herbicides is indicated.

Other cultural practices in tropical agriculture are undergoing review, and ' new ' ideas are being advanced. Even in plantation agriculture, such an experienced organization as the United Fruit Company has recently revealed experiments which indicate the desirability of departing from long-held ideas on irrigation of bananas by overhead sprinklers. In its October 1955 report to shareholders, the Company describes ' . . . an entirely new concept of irrigation . . . an idea to irrigate bananas under the plant instead of by overhead sprinkling or surface flooding. Preliminary results indicate big savings to come in material and water, to say nothing of greater efficiency in application '.

Similarly, ideas about spacing, shading, fertilizing and harvesting have undergone change. Without superior planting materials to begin with, however, newer techniques of this nature cannot be fully effective. This is especially true of tree crops where the planter must make an initial choice that is irrevocable. If his planting materials are not the best then available, he can hardly expect to compensate by various other methods for increasing yields. Thus, the discovery and provision of superior stock or seed is undoubtedly the most important single activity in the field of agricultural research.

Over the years there have been some spectacular increases in yields obtained from tropical crops of major importance. These have come mainly from constantly improved planting materials, but also from better, cheaper and tested fertilizing materials and from advanced planning of the productive layout and its upkeep. Cane sugar is a classic example of phenomenal increases in yields over a long period of time. It is, of course, the oldest crop cultivated by Europeans in the tropics, but its yield potentialities were not all realized at once. Technical improvements in cultivation

and processing were gradual but persistent and, with important advances in the use of commercial fertilizers, in the twentieth century yields were again doubled and trebled within a couple of decades (MASEFIELD, 1950, pp 150–152).

Rubber, a relatively new crop by comparison with sugar, has similarly made substantial progress in yield-betterment, although economic conditions did not favour much replanting for many years following the depressed 1930s. 'Whereas in the days of planting unselected seedlings 500 lb of rubber per acre was an average yield on good estates, clonal rubber on good land may now be expected to yield over 1 000 lb, and in the best conditions 1 500 to 2 000 lb is obtained' (ASHBY and PFEIFFER, 1956, p 146). More recently, experimental groves are reported to yield 2 000 lb or more of dry rubber per acre (*Wall Street Journal*, 1957). Closely associated with rubber yields per unit of area is, of course, optimum planting density, a matter upon which planters' views are apparently undergoing change (BAUER, 1948, pp 261–62).

Other tropical crops whose production has not been so greatly influenced by plantation research and methods show much slower development, even though striking potentialities seem to be present. Very high rice yields, for example, are obtained by both peasant farmers and plantations in a few favoured areas; or in countries where cultural techniques have been highly developed, where selected seed is used and where fertilizers are employed liberally (WICKIZER and BENNETT, 1941, pp 262–65). In contrast, the bulk of the world's rice is produced at a low yield level, by small farmers and by methods bound to centuries of tradition.

It is not surprising that a predominantly peasant-produced crop like cocoa has received relatively little attention from the scientists of tropical agriculture. Not until fairly recent years, when production was threatened by diseases and pests in both hemispheres, was much thought concentrated on learning about the crop and its problems. These belated efforts have been government- or industry-sponsored and financed. Out of such research have come conclusions that indicate high yield-potentials for cocoa, involving selected and improved planting material, and orderly arrangement of tree stands so as to permit easier and more effective disease control. Cultural practices in cocoa farming are generally of a low order, and the potentialities for improving yields are undoubtedly enormous. The use of superior planting stock alone has been variously estimated by authorities to have promise of multiplying yields some ten times (WICKIZER, 1951, pp 368, 442).

Even for coffee and tea scientific opinion holds that yields today can be doubled or even trebled through the use of better planting materials and improved cultural methods. Since both crops have long been largely plantation-produced, improvements have already been made leaving the potentialities for raising yields smaller than for cocoa. However, thoughts on planting density, shading and fertilizing are currently being entertained in coffee improvement; and for tea, in addition, planting arrangements and pruning techniques to permit mechanical plucking are being actively considered (WICKIZER, 1951, pp 428ff.).

Examples of research needs, past progress and future potentialities of

agriculture in the tropics could be multiplied. Despite limited finances and a shortage of trained scientific personnel, much useful work is being done today at research institutions and farms throughout the tropical world. Some investigations require many years for completion and hence have not received the same degree of support that has been given to short-term studies, yet their importance is frequently greater. Whatever the obstacles to more adequate research in tropical agriculture, they are probably less formidable than the problem of applying in practice the knowledge already gained. The difficulties go beyond extension work as such; they are frequently deep-seated in political and social considerations which have become more important than ever before in the organization and management of tropical crop production.

(*Received July 1959*)

REFERENCES

Ashby, D. G. and Pfeiffer, R. K. (1956). 'Weeds: a limiting factor in tropical agriculture', *World Crops*, June

Bates, W. N. (1957). *Mechanization of Tropical Crops*. London

Bauer, P. T. (1948). *The Rubber Industry*. London

Beckett, W. H. (1953). *Programmes and Plans for Rural Development in Tropical Countries*. International Institute of Differing Civilizations: Brussels

Capistraño, S. (1953). 'The practicability of mechanized lowland rice farming', *Philipp. J. Agric.* **18,** Nos. 1–4

Colonial Office. (1950). *Report of a Survey of Problems in the Mechanization of Native Agriculture in Tropical African Colonies*, London

Colony and Protectorate of Kenya. (1954). *Report of the Committee on African Wages*. Nairobi

de Briey, P. (1955). *International Labour Review*, August–September 1955, as extracted in *The Colonial Review*, December, under the heading 'The productivity of African labour'.

International Labour Review. (1950). September–October

Lefort, E. J. E. (1956). 'Mechanization of coconut growing', *Quart. Bull.* (South Pacific Commission), January

Lewis, W. A. (1950). 'Developing colonial agriculture'. *The Three Banks Review*, June

Lewis, W. A. (1955). *The Theory of Economic Growth*. Homewood, Ill.

Masefield, G. B. (1950). *A Short History of Agriculture in the British Colonies*. Oxford

Matheson, G. K. and Bovill, E. W., eds. (1950). *East African Agriculture*. London

Matthews, C. O. J. (1951). 'Agricultural labour and mechanization', *Caribbean Economic Review*, October

Mayne, J. E. (1954). 'Progress in the mechanization of farming in the colonial territories'. *Trop. Agriculture, Trin.* **31,** 178

Tropical Agriculturist. (1954). Editorial, January–March

United Nations, Food and Agriculture Organization. (1944). 'Considerations and procedure for the successful introduction of farm mechanization', *F. A. O. Development Paper No. 44*, Rome, June

Vaugh, M. (1954). 'Mechanization for the small farmer', *News Letter* (International Rice Commission, F. A. O.), June

Wall Street Journal. (1957). 11 October

Wickizer, V. D. (1951). *Coffee, Tea and Cocoa: An Economic and Political Analysis*. Stanford, California

Wickizer, V. D. and Bennett, M. K. (1941). *The Rice Economy of Monsoon Asia*. Stanford University, California

Land Use Projects in Cyprus

H. Hirst

Late Deputy Director of Agriculture, Cyprus

The Government of Cyprus through its 'land use' departments has, since 1945, embarked upon a number of development schemes aimed at making more land available to lack-land farmers. By the use of modern soil moving equipment, operated by its Land Use Section, the Agricultural Department has been able to develop considerable areas of Crown lands, which were under scrub forest, and also in one instance some compulsorily acquired estates which had been neglected under the ownership of absentee landlords. More recently the Department has gone to considerable trouble and expense to rip and rock-rake large areas of fairly level eroded land, covered by a cap of limestone of varying thickness and hardness, so as to render it suitable for cultivation.

In the lands known as the Paphos Chiftliks (estates) and the Ploushia Project, which it is proposed to describe in this article, the basic development work consisted mainly of deep ploughing, contour banking and the provision of a road system. On the two main estates of the Paphos Chiftliks, large areas of land could be rendered irrigable and the Water Development Department has constructed new, and improved existing, irrigation works. On both the projects reviewed the land has been laid out for a system of block farming, which in its simple form of a cereal/fallow rotation, is traditional in many parts of Cyprus.

A strong cooperative movement has been developed during the British occupation of Cyprus and the peasantry has become, in many respects, very cooperative minded. Taking advantage of this fact the tenants on the various projects are being encouraged to form Cooperative Farming Societies for various group farming activities such as the growing of permanent crops, including citrus, deciduous fruit, olives, vines and bananas. Efforts are also being made to establish cooperative flocks of milch sheep and also to start large-scale intensive livestock ventures with pigs and poultry.

The Cypriot farmer is used to village life and so far no effort has been made to establish homesteads on the land with the exception of two projects on which it was desired to settle persons from villages in remote forest areas. The tenants have always been drawn from neighbouring villages. No distinction has been made between the Greek and Turkish communities and as the tenants have drawn lots for balanced holdings the plots allocated to those from different villages and communities are intermingled. This, in spite of political trouble, has not resulted in any special difficulty except in one of the Paphos Chiftliks where tenants drawn from different villages did not wish to come under one Cooperative Farming Society and in fact formed two. Since doing so, however, they have decided to collaborate in the farming of areas of permanent crop land.

The development of the project has undoubtedly been retarded by the rather poor standard of the tenants, who were selected by local committees of government officials. In general tenants were required to have some land and to have the means of farming more. With a view to the formation of Cooperative Societies they were required to be credit-worthy. In early post-1945 years preference was given to ex-service men.

Had a policy been followed of calling for applications from all classes of farmers undoubtedly much more satisfactory types could have been secured. The projects have not been entirely without their political troubles. In one of the Paphos Chiftliks, known as Potima, the villagers from one area, where it was hoped to select tenants, were encouraged by left wing elements to press for the ceding rather than the leasing of the lands and the required tenants finally had to be drawn from a more distant village.

The tenants are being leased the developed lands, for varying lengths of time, at rents which are intended to give a reasonable return to Government (in the case of the Paphos Chiftliks, about 4 per cent on the capital invested). The tenants are required to follow a farming plan, approved by the Department of Agriculture, although they are allowed considerable freedom of action in many directions. The permanent crop land and the livestock ventures are being developed and maintained by Government, to a stage where they are in profitable production, before being taken over by the tenants.

The two projects under review have now been in existence for eleven and nine years respectively and their development has reached an advanced stage especially from the crop aspect.

The Paphos Chiftliks have been under the supervision of a Committee, consisting of the District Commissioner and the heads of the main departments concerned in their development, which sits under the chairmanship of the Director of Agriculture. This committee has been assisted by a local sub-committee consisting of officials concerned in the implementation of policy. The main committee has as its secretary the Agricultural Officer in charge of the Department's Farms, Stations and Nurseries, who also acts as its executive officer. The Paphos Chiftliks have been staffed by a full time manager, two agricultural assistants and two foremen who, among other duties, have been responsible for the development and maintenance of the permanent crop land. Of recent years a Land Settlement Officer, who has received specialist training under a F.A.O. Fellowship, has been stationed in the area.

In the case of the Ploushia Project, its supervision after the initial development has been entrusted to the District Agricultural staff assisted by a local committee which includes members of the Cooperative Farming Society.

Associated with the Achelia Chiftlik, the largest of the Paphos estates, is an Agricultural Department project which aims at showing how traditional forms of animal husbandry can be associated with dry land cropping, including pasture leys, on a self sufficiency basis. On the Ploushia Project the Agricultural Department has a demonstration holding on which a

comparison of high and low farming is being made. The following are further details of the two projects.

THE PAPHOS CHIFTLIKS

These are located on coastal lands in the south west of the island which enjoys a fairly equable climate. They cover a total area of 11 907 donums (3 969 acres) and consist of four estates, Achelia (5 273 donums), Kouklia (2 860 donums), Mamonia (2 912 donums) and Potima (797 donums). The first three estates have water rights to perennial flow rivers, the supply from which, however, must be supplemented by pumping from sub-surface water during the summer months.

Prior to 1948 these estates were owned by landlords living in Turkey. The lands were leased to individuals who in turn sub-leased them on a short-term basis to cultivators. They were far from well used. The land was badly exploited, available irrigation water was not always used effectively and on occasion was sold off the estates to the highest bidders. Government compulsorily acquired the estates, including some other lands which encroached on them. After acquisition all the lands were surveyed and classified. As a first step much of the land had to be fallowed to bring the heavy weed infestation, especially with *Imperata cylindrica*, under control. Some land, especially that on the Potima Chiftlik, required major works as regards the clearance of surface stones, the presence of which was accentuated by deep ploughing. The necessary field roads and culverts were made and irrigation systems were improved or newly constructed. Finally contour banks were thrown up for soil conservation purposes. On the two major estates the lands were divided into four more or less equally sized blocks, one of which was reserved for permanent crop cultivation and the other three for annual crops. Of these one is summer-irrigated by rotation for vegetable and legume crops. Each tenant initially had a plot of six donums in each of the three blocks to be devoted to annual cropping. They are to have a share in the permanent crop areas which will be collectively operated by the Cooperative Farming Societies. The tenants are required to farm according to a plan which initially provided for a winter legume/cereal/summer crop rotation on the annual crop blocks. The crops grown are as follows:

Winter legumes	Broad beans, chick peas, lathyrus, vetches, lentils
Cereals	Wheat, barley
Summer crops	Cowpeas, melons, tomatoes, cotton, sesame, haricot beans, hemp
Permanent crops	Vines, citrus, bananas, olives, carob, almonds, pecan nuts, miscellaneous deciduous fruits, lucerne.

There have been delays in the planting of the permanent crops because of the need to establish windbreaks and to deal with weed infestation, but by the end of 1958 most have been established and some, such as vines and bananas, were already in bearing and had been handed over to the Cooperative Farming Societies which had been formed, at that time, by the tenants.

The tenants on the two main chiftliks were required to serve a probationary period. In a few instances some difficulty has been experienced in the collection of rents which were fixed at £1 per donum per annum. It is not thought that further difficulty in this respect will be experienced now

that the Farming Societies, which are responsible for the collection of rents, have been formed. A few tenants have been troublesome by failing to follow the farming plan. Some, for example, planted cereals on the winter legume block.

Because of the delay in establishing cooperative sheep flocks the tenants have been allowed to modify the rotation to allow two thirds of their annual crop plots to be under cereals for two years out of the three. This appears to have given general satisfaction.

There has also been a little friction with the tenants over the use by Government of irrigation waters for the maintenance of the permanent crops during periods of water scarcity but this has not been of a serious nature.

The Cooperative Farming Society on the Achelia Chiftlik has acquired a flock of sheep, which include imported Chios and Sardas, and Government has built them a sheep fold which the Society leases.

A large-scale poultry unit, which is being stocked initially with 10 000 layers, has also been established on the Achelia Chiftlik. The poultry are kept in flock houses sited in an area of the permanent crop land devoted to the growing of olives. Initially this unit will be run in conjunction with a breeding poultry unit which is already being operated in the vicinity by the Agricultural Department. If, as is hoped, the unit proves financially successful, it will be turned over to the Cooperative Farming Society.

Figure 1. Part of the Pig Fattening Unit on the Achelia Chiftlik (Estate). This unit with its supporting breeding unit is now in full production and turns out 800 fattened pigs per year

On both the Achelia and Kouklia Chiftliks intensive pig fattening units are being established, each having an output of 800 fatteners per year. As a start they are being supported by Government-operated breeding units but it is hoped in due course either to have the tenant produce the weaners or to produce them intensively under an artificial brooding system. As with the poultry unit it is intended that the pig units should be run in due course by the Cooperative Farming Societies.

The object in establishing the intensive livestock units on the estates is twofold. First to capitalize further the holdings which it is realized are too restricted in size to give a good living solely from crops, and secondly to supplement the island's supplies of livestock produce which are not meeting present day requirements. The estates will be able to furnish the barley, which will comprise some 60 per cent of the concentrate ration, and the green fodder. The livestock units will furnish organic manure for the citrus groves which have been established.

Less progress has been achieved with the other two estates of the Paphos Chiftliks. One, Mamonia, although slightly larger than Kouklia, consists

Figure 2. A young banana plantation in the Kouklia Chiftlik (Estate). A cane windbreak can be seen in the left background while on the right are carob trees. The first of the banana plots at Kouklia have now been taken over by the Cooperative Farming Societies and are proving very profitable

for the most part of steep, poor lands much of which are unsuitable for cultivation. The estate has been divided into three areas (*a*) steep poor lands unsuitable for cultivation (1 000 donums), (*b*) better quality but sloping lands (762 donums) and (*c*) irrigable river bed lands (450 donums). The three portions are rented on short-term leases to different groups of tenants. Soil conservation works, stone clearing and deep ploughing have been carried out, mostly on the better lands. It is hoped in due course to develop all the lands so that individual tenants can be given land in each of the three areas and that the poorer steep lands will be developed for pasturage.

As regards the Potima Chiftlik, the tenants formed a Cooperative Farming Society initially and the lands have been leased to the society for 30 years. The lands are being farmed on a block system similar to that on the two major estates. Good use has been made of the limited supplies of irrigation water, and vegetables and other irrigated crops have proved profitable. Trouble has been experienced in trying to establish an area under vines. Damage by sea spray caused the area selected to be abandoned and it is being cultivated collectively under annual crops. A cooperative-owned flock of sheep has proved profitable although some difficulty has been experienced in persuading the tenants to grow special forage crops for its consumption during periods of sparse feed. Progress in general made by the Cooperative Farming Society on this particular estate has not come up to early expectations.

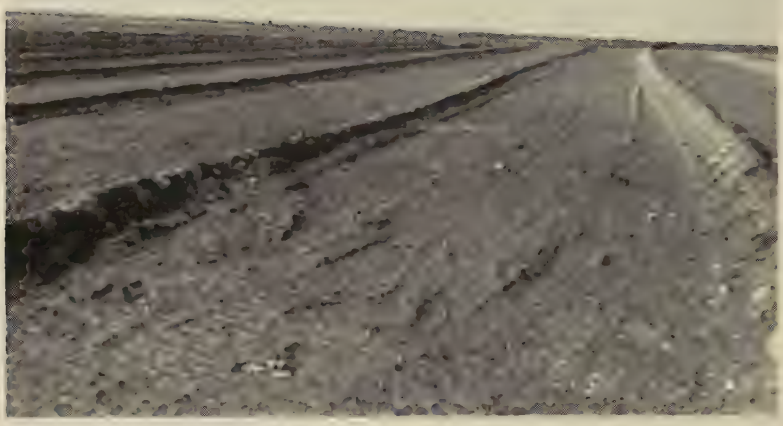

Figure 3. The levelling of land on the Achelia Chiftlik (Estate) for the border irrigation of permanent crops. The irrigation water supply comes from the nearby river. In summer the river flow is supplemented by sub-surface pumping in the river bed

Figure 4. A view of the Ploushia lands with the foothills of the Kyrenia Range in the background. In the foreground is the stubble of Phalaris tuberosa *which has been grown in rows*

THE PLOUSHIA SCHEME

This scheme covers an area of some 4 000 donums (1 330 acres) of Crown land in the southern foothills of the eastern end of the Northern range of mountains. The land, which is of a sloping nature, is in what is known as a minor (scrub) forest area. Prior to 1949 about half of the area was leased for a nominal rent of 1*s* per donum to individuals from neighbouring villages. Some did not cultivate the lands personally but sub-leased to others, often at a considerable profit. The development of the area, which will take some 12 years to complete, was aimed at obtaining a greater and more economic production from the land. Efforts were made to see that the most deserving lack-land farmers from the nearby villages enjoyed tenancy. The area was selected to serve as a pilot project with a view to the adoption of the same development techniques in similar areas of land throughout the island. The works envisaged consisted of the improvement of existing cultivable areas and the development of others to render them cultivable; the planting of trees such as carob, olive and almond on the contour banks; the promotion of controlled sheep grazing under cooperative ownership; the development of very limited water resources for the use of livestock and for irrigation. It was estimated that when the trees come into production the gross return from the land will be in the neighbourhood of £21 000.

So far the land has been leased to 51 tenants in holdings of approximately 50 donums (about 17 acres), for two periods each of four years. Each holding consists of a plot in each of four blocks. The tenants have been given an assurance that if they farm satisfactorily they will be allowed to continue to lease the land and provision is made for their heirs to take over the tenancy in the event of death. The rent is fixed according to the value of a given quantity of wheat, at present 5 okes (14 lb) per donum. So far only the land itself has been leased. When the trees, which are being established by the Department, come into bearing they will be leased separately.

Although the Department has not provided any full-time officers to supervise the long-term development of the area it has established a project holding on some 150 donums of land on which a comparison is being made of high and low farming with a sheep flock as the principal source of revenue. This project, until its buildings were damaged by sabotage, served as an excellent demonstration to the tenants, showing the advantages of adopting modern production techniques including the use of good seed of varieties of cereals suited to the area; the use of fertilizers, especially top dressing with nitrogen; the use of chemical weedkillers and the introduction of new varieties of fodders.

The establishment and maintenance of the twelve thousand trees on the contour banks is proving a rather difficult task, involving as it does their frequent irrigation in the early stages of establishment. It is already becoming apparent that planting in the contour banks may have been a mistake and that the trees might have been better established in special areas. Their presence prevents the banks being cultivated, with the result that much weed growth takes place. This, as experience has proved, provides a fire hazard. It is also apparent that it will be difficult to establish

the cooperative flock until the growth of the trees takes them out of reach of grazing animals. Some illicit grazing takes place, especially at night, which has resulted in considerable damage to the young trees. Little interest has been shown by the tenants in the development of irrigated land and this part of the project has been left in abeyance. Some little trouble is also being experienced from persons from one of the nearby villages who feel that a larger proportion of the holdings should have been allocated to them. As a result tenants from this particular village show a reluctance to collaborate with those from others.

Nevertheless in spite of these difficulties encouraging progress is being made and it is apparent that much more intensive use is being made of the land than formerly.

REVIEW

A description has been given of two farming projects being developed by the Government of Cyprus on Crown lands. In one project neglected lands were compulsorily acquired from absentee landlords, and the other was developed from scrub forest. The Government has sought *inter alia* to experiment in the establishment of a mode of farming which, while not new to the Cypriot peasantry, who have traditionally farmed dry lands on a block system, involves a cooperative approach to a much more diversified system of agriculture than that to which the selected tenants have been previously used. It cannot be denied that a certain amount of coercion is involved in the early stages. The tenants have been left to reside in their villages, and are allowed to continue to farm lands they previously owned or leased. Initially they were required to adopt a system of arable farming, suited to the area, with a cautious approach to the adoption of group farming techniques. After the formation of Cooperative Farming Societies the tenants are being encouraged to take over, for collective or other forms of farming, blocks of land under permanent crops which have been brought to the productive stage, by Government, through the injection of development capital. Finally the Cooperative Farming Societies are to be encouraged to take over sheep flocks and intensive animal husbandry ventures which will largely depend on the production of the land.

Government aims at securing a return of about 4 per cent on the money it is investing. Credit for the members is initially provided through the village cooperative credit societies. Once the cooperative farming societies are established they become responsible for the provision of credit to the members and it is hoped that they will assume responsibility for the marketing of produce, especially from the collectively run enterprises.

(*Received September 1959*)

A Review of Some Limiting Factors in the Nutrition of Cattle on the Accra Plains, Ghana

T. J. Lansbury
University College of Ghana

Recently much publicity has been given to the drive for increased cattle production in Ghana, and some positive measures are being taken to bring about the desired increase on the Accra Plains and in other savanna areas.

Because the 30 in. average rainfall on the Accra Plains is very unevenly distributed over the year, falling mainly in two peak periods around June and October but with great irregularity, one of the first priorities has been to provide adequate and constant water supplies. No animal can achieve its optimum food intake, digestion and subsequent metabolism of digested nutrients without adequate water. Furthermore, although in times of famine an animal can lose over half of its body fat without harm, the loss of one tenth of its body water can cause serious debility and death. Proper distribution of water supplies is equally important since time spent walking to water is time lost as far as grazing is concerned. During the dry season this may be a very serious factor when the animal has to work hard to find enough food in the time available for grazing, quite apart from the fact that food has to be found, digested and metabolized into the energy used in the process of walking long distances to water points. This priority requirement for water has obviously been recognized and it is to be hoped that the proper siting of grazing camps in relation to water supply will follow, in order to avoid overgrazing in areas close to water points or excessive walking distances.

After water supplies, the most evident priority is the provision of food for the dry season. Some preliminary observations at the University College Agricultural Research Station, Nungua, indicate that where water supplies are adequate and close to grazing areas, and twenty-four hour grazing is allowed, the requirement for supplementary feeding, as measured by weight loss, is reduced. None the less there is, even in the mildest dry season, a substantial weight loss indicating a substantial need for supplementary feeding (Thomas, 1954; Rose Innes, 1958). In a recent feeding trial in Northern Nigeria, bullocks grazing in the dry season responded markedly to small quantities of balanced concentrates (Miller, 1959). The bullocks received a groundnut cake and sorghum supplement equivalent to 1·7 lb starch equivalent and 0·6 lb digestible crude protein daily, and were able to gain nearly 60 lb over a dry season grazing period

of twenty weeks whereas control animals, on grazing only, lost about 19 lb. Such large differences would probably not be sustained through the following wet season, since Miller suggests that animals are capable of more rapid growth during the period of recovery after weight loss. AINSLIE (1958), under milder dry period conditions in Rhodesia, has reported this phenomenon of rapid recovery after periods of malnutrition, but despite this it is clear from field observations that a delay in reaching slaughter weight still occurs.

Some people think that under extensive management in the tropics, the animals' first requirement is ' food of any sort '. In fact, early work in Northern Nigeria (BROWN, 1938) has shown that poor quality hay, fed as a supplement to cattle on dry season grazing, actually depressed normal liveweight increase. Brown suggested that the poor quality hay used up more energy in digestion than the digested portion was able to supply. From digestion trial results with hay at Nungua (LANSBURY, 1958a) this seems unlikely to be the true explanation. The reason for the depression of liveweight increase is probably associated with the appetite or capacity for food intake of the animal. Cattle in general have a dry matter intake ranging from about 3·5 to 1·5 per cent of the liveweight of the animal per day, depending on the stage of growth or production. Presumably in Brown's experiments the quality of hay fed was lower than that of the grazing and while the animals could just obtain enough of the essential nutrients from a full belly of grazing, the supplementary hay reduced the total intake of nutrients from grazing plus hay to a level which was below the nutritional requirement of the animal.

It is clear then that what has to be considered in a discussion of supplementary feeding is the level of essential nutrients that is likely to be a limiting factor when the appetite of the animal is taken into account. The mature fattening animal has a lower appetite than a young growing calf and in addition it is probable, under hot humid conditions, that appetite is voluntarily decreased as a heat tolerance mechanism. Bearing in mind that appetite is also a function of the quality of food offered, it is doubtful whether the dry matter appetite of cattle on the Accra Plains is likely to exceed 2·5 per cent of liveweight, even allowing for a supposedly greater intake in the case of Zebu and Zebu cross cattle. Appetite trials with stall fed cattle at Nungua gave results ranging from 1·5 per cent to 2·8 per cent but 2 per cent would probably be a good working estimate, a value which is confirmed by Miller in Northern Nigeria.

Digestion trials at Nungua have shown that due to the high digestive efficiency of the West African cattle used, all but the very coarsest fodders of extremely high fibre content are capable of meeting the digestible energy requirements of cattle for maintenance. Several feeds, however, were too low in protein to meet the digestible protein requirements for maintenance. Consequently although ' food of any sort ' may provide adequate energy it is clear that it will not necessarily meet the protein requirements, and liveweight losses may follow through the katabolic destruction of tissue by the animal in its efforts to make up for nitrogen losses due to normal wear and tear of tissues and nitrogenous secretions. A recent experiment at Samaru in Nigeria (MILLER, 1959) compared energy-rich food (cereals)

with protein-rich food (groundnut cake, etc.) as supplements to dry season grazing. There was very little response to the cereals but a marked response to the protein concentrates.

Of all the requirements for major nutrients, that of protein seems to be the least well defined. The subject has recently been reviewed by ROY (1958) and DODSWORTH (1958). From these data a fair estimate of the minimum protein requirement of a 500 lb bullock would seem to be about 0·3 lb digestible protein per day, but OYENUGA (1958) quotes Indian work as placing the maintenance requirement for protein of cattle in the hot tropics 25 per cent below that of cattle in temperate climates. For rapid rates of growth between 0·5 and 0·75 lb digestible protein would be required.

Most of the hays and silages examined at Nungua (LANSBURY, 1958a, 1958b, 1959a) were unable or barely able to supply the required level of digestible protein at the dry matter appetite level of 2 per cent of the liveweight. In *Table 2* the lowest value, allowing a small safety margin, for protein requirement has been used to show the level of protein needed in a feed in order for it to be effective as a dry season supplement in relation to an animal with a dry matter appetite of 2 per cent of the liveweight. This is compared with the intake of digestible protein from Nungua feeds at this appetite level.

Table 1. Nutritive values of Nungua fodders on a dry matter basis as calculated from digestion trial results

Feed	*Starch equivalent*	*Digestible protein, %*	*Nutritive ratio*
Hay (Sand soil)	44	2·5	18
Hay (Clay soil)	37	1·3	32
Rice straw	41	1·2	35
Young Guinea corn silage	47	5·4	9
Poor quality millet silage	37	1·3	29
Good quality millet silage	51	1·6	32
Mature Bana grass	48	2·3	20
Centrosema	43	11·5	4
Guatemala grass	58	7·1	8
Young Guinea grass (Rainy season)	60	6·5	9
Green maize at milk to dough stage	40	6·5	6
Very young fodder millet	60	10·6	6
Millet and velvet beans	52	5·7	9
Older millet and velvet beans	49	3·1	16

An arithmetical conclusion to be drawn from *Tables 1* and *2* is that in order to supply the maintenance requirement of a 500 lb bullock with a dry matter appetite of 2 per cent of its liveweight, fodder needs to have at least 3 per cent digestible protein on a dry matter basis. In order to supply maintenence and a liveweight increase of the order of 1 lb per day, fodder needs to have upwards of 5·5 per cent digestible protein.

As a general conclusion, it seems that fodder conservation, whether as hay or silage, must be planned with a careful watch on the probable digestible protein content of the finished product. It is here that stage of growth, at the time of cutting, is important, as can be seen from *Table 2* in the case of millet and young Guinea grass. The large-scale production of low protein fodders could have disappointing results and might not justify the cost of

Table 2.

(a) The estimated digestible protein requirement of a 500 lb bullock for maintenance and maintenance plus production of up to 1 lb per day liveweight increase

Maintenance 0·25 lb	*Maintenance plus production 0·5 lb*

(b) The estimated digestible protein intake of a 500 lb bullock with a dry matter appetite of 2·0 per cent of its liveweight (10·0 lb) when fed Nungua fodders

Feed	*Protein intake lb*	*Protein intake as % of requirement*	
		Maintenance	*Maintenance plus production*
Dry roughages			
Hay from sand soil	0·25	100	50
Hay from clay soil	0·13	52	26
Rice straw	0·12	48	24
Silage			
Young Guinea corn silage	0·54	216	108
Poor quality millet silage	0·13	52	26
Good quality millet silage	0·16	64	32
Green fodders			
Mature Bana grass	0·23	92	46
Centrosema	1·15	460	230
Guatemala grass	0·71	284	142
Guinea grass	0·65	260	130
Green maize (milk to dough stage)	0·65	260	130
Very young millet	1·06	424	212
Millet and velvet beans	0·57	228	114
Older millet and velvet beans	0·31	124	62

production. Green fodders, rich in protein and also Vitamin A precursors, which can be grown in wetter low-lying areas, in seepage areas below dams or even under irrigation, offer a far more nutritionally satisfactory prospect than dry roughages, cereal or grass silage, and might be used in systems of complementary grazing. From experiments in Queensland (NAGLE, 1959), there can be little doubt that green fodders are far more effective than grassland in the utilization of limited quantities of irrigation water. Nagle reports yields of 10 to 15 tons per acre of fresh green fodder from 5 to 6 inches of irrigation water in a growing period of 6 to 10 weeks, which is in line with results obtained with fodder millet at Nungua (LANSBURY, 1959b). What is doubtful is whether the growth of these fodders for the indirect production of human food by means of ruminants, having a conversion efficiency of only about 17 per cent, is justifiable when the irrigated or wet land could be used for the direct production of human staples.

The use of feed urea does not appear to have had serious consideration in British West Africa apart from some preliminary work by BLAIR RAINS at Samaru (1959). This may be a heritage of the disappointing results obtained by British research workers during 1939–45. However, it is now recognized that where, as in the areas of America and South Africa in which urea has been used successfully, there is a plentiful supply of starchy foods, urea may play a valuable role in supplying the nitrogenous base on which rumen bacteria may build up amino acids and ultimately protein (Allied Chemical, 1954; HUMPHREY, 1956). Experiments in North Queensland,

Australia (MORRIS, 1958), using urea as a supplement to sorghum silage have been highly successful under conditions not unlike those met on the Accra Plains. Certainly the use of urea and related substances as a supplement to silage or in conjunction with by-products of the proposed sugar-cane industry deserves serious investigation in Ghana.

Quite apart from the two major nutrient requirements, that is to say energy and protein, the possibility of other limiting factors needs attention. The bleached dried-up appearance of the Accra Plains over much of the year is due to the fact that most of the grassland is little more than standing hay from which most if not all of the Vitamin A or its precursors are likely to have been lost. Although no work has been reported in Ghana on this subject it seems likely from Californian results (MORRISON, 1949a) that cattle grazing for long periods on such grassland would be suffering from Vitamin A deficiency which may be manifested subclinically by low growth rates and low reproductive ability. This deficiency is undoubtedly alleviated to some extent by the presence of ' browse ' trees and shrubs which continue to supply green leaves throughout the dry season and may be able to meet the quantitatively low requirement of about 30 mg beta-carotene per day in some areas. These browse trees and shrubs may also be a useful source of protein and phosphorus since from the data of NYE (1958) it can be seen that the nitrogen and phosphorus levels of coastal thicket leaves may be between 4 and 5 times the natural grassland levels.

As a limiting factor phosphorus has not received a fraction of the attention it deserves. Generally speaking the savanna lands of Ghana and especially the Accra Plains are notably deficient in soil phosphorus (NYE and BERTHEUX, 1951). Herbage levels of phosphorus are closely related to soil phosphorus. Herbage samples from Nungua grassland have been found to be grossly deficient in phosphorus, their phosphorus content ranging from 0·14 per cent of the dry matter in the case of young grass to 0·05 per cent in dry season grazing (NYE, 1958; LANSBURY and ROSE INNES, 1959). It is generally recommended that phosphorus should not fall below 0·3 per cent of the daily intake of dry matter, and 0·15 per cent phosphorus has been considered the minimum level below which serious consequences can be expected (MORRISON, 1949b). In view of the exceedingly low level of phosphorus in the Nungua herbage, from both Akuse clay and Simpa sand soils, which represent a high proportion of the Accra Plains, it is surprising that serious manifestations have not appeared. It is well known, however, that succeeding generations reared on phosphorus-deficient soils may adapt themselves by reduced size and slow growth as have the dwarf cattle of Brittany and possibly the Shetland pony. This may be a partial reason for the rather small cattle, slow rate of growth and low reproductive rates found on the Accra Plains, quite apart from the dwarfing effects of climate and low overall plane of nutrition described by OYENUGA (1958). The danger of more acute phosphorus deficiency may arise as attempts to increase the size and rate of growth of these cattle by cross breeding bear fruit. The deficiency is likely to be further aggravated by the fact that calcium levels in the herbage are high, resulting in very wide calcium/phosphorus ratios, which may further inhibit the normal absorption and metabolism of phosphorus.

In view of the extreme deficiency of phosphorus described above and of the fact that herbage protein levels are also adversely affected by low soil phosphorus, there may be a case for utilizing some of the cheap rock phosphate available from neighbouring French territory as a top dressing on grassland, at any rate on a field trial basis. It is possible, however, that the rock phosphate may be unsuitable due to the presence of fluorides or low availability of soluble phosphate, quite apart from its reduced effectiveness on soils of high pH. A more direct utilization of this rock phosphate as a feed supplement might depend upon defluorination. This is by no means an insurmountable problem and might be tied in with the existing local pottery kiln industry.

A commercial firm in East Africa has marketed a supplement based on urea, calcium, phosphorus, Vitamin A and trace minerals. It is likely that such a supplement would also prove satisfactory in Ghana and might well be a valuable tool in providing effective dry season supplementation where normal supplements such as grass silage or hay are limited in their effectiveness by deficiencies in one or all of these components.

In view of all that has been said so far, it is perhaps surprising that the cattle of the Accra Plains have an aura of good health and thriftiness, except during periods of severe famine.

It should be recognized, however, by agricultural research and development officers as well as by veterinary officers, who are aware of the fact by virtue of their professional training, that there are degrees of nutritional deficiency (or disease) from repletion on the one hand to advanced pathogenesis on the other. Nutritional status may pass through a phase of unsaturation to deficiencies of specific factors which may not cause pathological disorder but put the animal in a state of potential disease where sudden stress may precipitate serious disorder. At Nungua, for instance, apparently healthy poultry on a borderline level of calcium intake become badly lame or paralysed when put into battery cages for the first time. Conversely, resistance to trypanosomiasis in Zebu cattle was markedly increased by better nutrition in trials by HILL (1956) at Ibadan, Nigeria. Equally the animal may be in a state of latent or subclinical nutritional disease where obvious manifestations are absent. What is most important is that the possible existence of subclinical nutritional deficiencies should be recognized and investigated before large-scale attempts are made to improve the performance of existing cattle without adequate reference to the nutritional environment.

Too frequently it is heard that Ghana needs better cattle, better grasses, etc; what is usually overlooked is that 'better' is not synonymous with 'higher yielding' in its grossest sense. Grasses can only do what the soil will allow them to do. Many of the grasses in Ghana today are recognized as the best grasses for their environment. High yielding grasses could not live on the Accra Plains soils, which cannot supply the water and food they need. Exactly the same applies to high yielding cattle. Higher yields need a higher nutrient intake and if the food is not there, neither the grass nor the animal can live. The existing grassland is capable of growing on the Accra Plains soils although yields are poor. Our small slow-growing cattle can live on the low yielding grassland where high yielding cattle

might not. 'Better' grasses and 'better' cattle under present conditions are those which can more efficiently convert what little soil fertility there is into products for human consumption and we have yet to find where and what those grasses and cattle are. Agriculturalists cannot afford, however, to be too static in their approach and there is still room for a more dynamic approach to grassland improvement. Although fertilizer trials on natural grassland of the Accra Plains at Nungua (HAGENZIEKER, 1956) gave significant responses to nitrogen and phosphorus, the yields were too low to make fertilizer application pay. This was probably due to the development of species and strains, after thousands of years of natural selection under traditional grazing and burning practices, which were there because of their tolerance of low soil fertility conditions. No marked response to fertilizer could be expected from these strains without a long process of backward evolution. On the other hand, the use of new high yielding grasses, capable of responding to fertilizer, could well make the application of fertilizers economic but only under more intensive grassland utilization systems than have been considered necessary or practicable so far, under the socio-economical conditions prevailing.

CONCLUSION

From the few experimental data presented it is difficult to argue a case for specific direction of future effort. It would seem that at present the growth of special fodder crops for dry season feeding offers the best solution to the problem of provision of dry season fodder in terms of yield and economic use of fertilizer. This, however, can only be done by placing cattle in direct competition with man for arable crop products, a situation which is highly undesirable in a country where human staples are sometimes near famine levels. It is also a nullification of the very advantage which we should be exploiting, that is the ability of ruminants to convert grassland into animal products of the highest nutritional value, without competition for technical resources, which could be better applied to arable food crops for man. Perhaps the first step should be to bring existing grassland up to its optimum value by supplying the missing or deficient constituents which at present limit its value. With two of these constituents, that is protein and phosphorus, we have definite evidence of deficiency supported by responses to their beneficial effect when fed as supplements elsewhere (MILLER, 1959). The immediate problem is how to supply these nutrients in a sufficiently cheap and simple form and it is here that very simple supplements based on urea and phosphates may have a role to play which should receive all the investigational support that can be mustered. Once we have learned how to balance existing grassland to its optimum nutritional value the next step will be the quantitative improvement of our cattle food supplies by irrigation, conservation or the utilization of cheap by-products.

ACKNOWLEDGEMENTS

The author wishes to make acknowledgements to Mr R. ROSE INNES, Dr V. A. OYENUGA, and Dr T. B. MILLER who have provided many of the ideas and much of the data in this article; to Mr HUTCHINSON, Chief Veterinary Officer, for facilities provided at the Nungua Animal Health

Station; to Professor J. F. V. PHILLIPS and Mr P. R. HILL for facilities and encouragement at the Faculty of Agriculture Research Station; and lastly to the Ghanaian Cocoa Farmers whose support makes the station possible.

(*Received December 1959*)

REFERENCES

AINSLIE, K. S. (1958). *Rhod. agric. J.* **55,** 286

Allied Chemical and Dye Corporation, New York, Nitrogen Division. (1954). *Feed Urea in Ruminant Nutrition*

BROWN, J. D. (1938). *Third West African Agricultural Conference.* Government Printer: Lagos

BLAIR RAINS, A. (1959). Grassland Research Officer, Samaru, N. Nigeria, private communication of unpublished data

DODSWORTH, T. L. (1958). *Proceedings of a Conference on the Scientific Principles of Feeding Farm Livestock.* Farmer and Stockbreeder Publications Ltd: London

HAGENZIEKER, F. (1956). Private communication of unpublished data

HILL, D. H. (1956). Faculty of Agriculture, University College, Ibadan, Nigeria, unpublished report

HUMPHREY, K. (1956). *Rhod. agric. J.* **53,** 241

LANSBURY, T. J. (1958a). *Trop Agriculture, Trin.* **35,** 114

LANSBURY, T. J. (1958b). *Trop. Agriculture, Trin.* **35,** 289

LANSBURY, T. J. (1959a). *Trop. Agriculture, Trin.* **36,** 65

LANSBURY, T. J. (1959b). *Trop. Agriculture, Trin.* **36,** 305

LANSBURY, T. J. and ROSE INNES, R. (1959). Unpublished data

MILLER, T. (1959). Agricultural Chemist, Samaru, N. Nigeria, private communication, unpublished data

MORRIS, J. G. (1958). *Q d J. agric. sci.* **15,** 161

MORRISON, F. B. (1949a). *Feeds and Feeding,* Vol. VII, p 142. Morrison Publishing Company: New York

MORRISON, F. B. (1949b). *Feeds and Feeding,* Vol. VIII, p 277. Morrison Publishing Company: New York

NAGLE, A. (1959). *Q d agric. J.* **85,** 426

NYE, P. H. and BERTHEUX, M. N. (1951). *J. agric. Sci.* **49,** 141

NYE, P. H. (1958). *J. W. Afr. Sci. Assoc.* **4,** 31

OYENUGA, V. A. (1958). *Nutr. Abstr. Rev.* **28,** 985

ROSE INNES, R. (1958). Private communication, unpublished data

ROY, J. H. B. (1958). *Proceedings of a Conference on the Scientific Principles of Feeding Farm Livestock.* Farmer and Stockbreeder Publications Ltd: London

THOMAS, F. (1954). Private communication as Senior Livestock Officer, Department of Animal Health, Ghana

Defaecating Habits of a Herd of Zebu Cattle

K. W. Harker

Animal Health Research Centre, Entebbe, Uganda

Although the usual practice in Uganda is to allow cattle unlimited grazing during the day and to herd them into kraals at night, the use of paddocks for night enclosures is rapidly gaining popularity. One of the chief benefits of this system is an increase in the fertility of the areas paddocked at night, but this has led to the assumption that more dung is dropped at night than during the day. In order to investigate this theory, the defaecating habits of a small breeding herd were studied at Entebbe.

Defaecating habits have been recorded by Williams and Bunge (1948) at Serere, in the Eastern Province of Uganda. They noted the grazing watering and excretory habits of one bullock during the rains and during the dry season. Their observations were continued for three days at each season and included the number of times dung was dropped and the weight of dung, but no management differences were imposed.

At Entebbe, the grazing habits of a small herd of Zebu cattle have been recorded, and the records have been made under both free grazing and under night paddocking systems (Harker, Taylor and Rollinson, 1954 and 1956). The excretory habits, however, were not recorded. Preliminary trials had shown that habits such as defaecation, which occupy a small proportion of the day cannot be recorded accurately using the same technique as that used for recording major habits such as grazing and ruminating (Rollinson, Harker, Taylor and Leech, 1956).

The object of the present trial periods was to gain information on the distribution of dung by Zebu cattle with reasonable pasture conditions under free range grazing and under free range combined with night paddocking conditions.

MATERIALS AND METHODS

For two periods in October 1956 and two in February 1957, the dung was collected from the same herd of Zebu cattle. During the first period, 9 to 15 October, the animals grazed freely on a single paddock, but during the second period, 24 to 30 October, the animals were put in a separate small enclosure between 7.00 p.m. and 7.00 a.m. During the third period, 4 to 10 February, the times of movement of animals were the same as in the second period, i.e. 7.00 a.m. and 7.00 p.m., whilst in the final period, 11 to 17 February, the animals were placed in the night enclosure from 4.00 p.m. to 8.00 a.m.

The animals used were a herd which is kept specifically for animal behaviour studies. The herd was formed in September 1952 and, except

for a few days, the parents and their progeny have been kept together under free grazing conditions ever since. When these defaecation studies commenced, the herd consisted of twenty animals of which nine were over four years old and seven were between two and four years of age. During the interval between the first two periods of study, a further calf was born. At the routine monthly weighing on 2 October, the cattle two years old and over ranged in weight from 296 to 618 lb.

The main grazing paddock was sown to *Chloris gayana* in November 1954. Before this trial, a botanical estimate showed that the main cover was provided by *Paspalum commersonii* and only 20 per cent by *Chloris gayana*. Other grass species contributing to the grazing were *Panicum maximum* and *Hyparrhenia dissoluta*. In small areas up to 50 per cent of the herbage was derived from the indigenous legumes *Vigna gracilis* and *Teramnus labialis*. Browse was obtained from the leaves of a few *Indigofera* sp. shrubs which grow to about 4 ft high, and also from the aerial shoots of *Justicia flava*, a plant which forms dense leafy beds along the fence lines and under the trees.

For this trial, this main paddock was subdivided into small areas of approximately 0·4 acre each by electrified fencing. The animals were moved on to fresh grazing at 10 a.m. on the first day of each of the first two collection periods and were moved to fresh grazing at 10 a.m. every second day thereafter. Similarly, during the third and fourth periods, the animals were given fresh grazing at 7 a.m. and 8 a.m. respectively every other day.

Herbage production over the paddock was very variable. Sample cuts, taken on the morning of 9 October, indicated yields of from 2 300 to 6 000 lb of dry matter per acre, with a mean of 3 800 lb. A bulked sample from these cuts gave an analysis of 9·4 per cent crude protein and 30·8 per cent crude fibre.

The small night paddock used for the second, third and fourth periods of the investigation was an area of unimproved rough grazing. For this trial, extra fencing was put round one tenth of an acre and the tufted grass, *Eragrostis blepharoglumis*, was dug out. This left almost bare ground with a few small areas of *Eragrostis mildbraedii* and *Digitaria scalarum*. Water was available in both the day and the night enclosures.

Dung was collected daily at 7.00 a.m., 10.00 a.m., 4.00 p.m. and 7.00 p.m. during the first two periods of study; at 7.00 a.m. and 7.00 p.m. during the third period and at 8.00 a.m. and 4.00 p.m. during the fourth period. Each dung pat was collected separately and placed on a tray. Except for the first 24 hours of the first period of study, when each dung pat was weighed separately in grammes, the dung pats were counted into buckets and each bucket weighed to the nearest quarter pound. The total bulk of dung at each collection time was sampled to give a sub-sample of approximately 1 000 grammes. In the laboratory, each sub-sample was thoroughly mixed and a portion of approximately 100 g was weighed accurately and dried rapidly to constant weight at 102°C in an oven with an air circulating fan.

RESULTS

The results from the first two collection periods served a dual purpose. First they gave data on the defaecating habits of the herd of Zebu cattle

and, secondly, they provided information on the design and execution of this type of trial. After the tentative results and conclusions had been drawn from these first two periods, the second two periods of collection were started. Consequently, the results of periods one and two will be given here separately before the results of periods three and four.

(A) Results and conclusions for collection periods one and two

The weights of faeces produced each day and the percentage distributions of faeces on a dry matter basis are given in *Table 1*. In calculating the percentage distribution each 24 hour period, starting at 10 a.m., has been regarded as a separate unit. The data given in this table should be considered in relation to the variable length of collection period. If the distribution of dung dropping is constant throughout the day, the percentages in the second, third, fourth and fifth columns should be 25, 12·5, 50 and 12·5 respectively.

Within very broad limits, this is true, but there are considerable fluctuations from day to day and from period to period. The biggest differences between periods are shown by the two collections of three hours dung production—that is the 4 p.m. to 7 p.m. collection and the 7 a.m. to 10 a.m. collection. This may be a true difference or may be a function of the time interval. Since the dung took at least half an hour to collect, any slight difference in the times of starting and ending would have the most effect on the short time interval. This indicates that short or variable collection intervals should be avoided. Similarly, as the animals were in two different paddocks during the second period of collections and were moved at a definite time, the results for the 7 p.m. to 7 a.m. and the 4 p.m. to 7 p.m. intervals should be more accurate than the results for the same time interval during the first period of collection when the animals were on one paddock only.

Table 1. Dry weight of faeces collected expressed as a percentage of the day's production, and the dry weight of faeces produced

	Percentage				
Period I	*10 a.m. to 4 p.m.*	*4 p.m. to 7 p.m.*	*7 p.m. to 7 a.m.*	*7 a.m. to 10 a.m.*	*Total weight of dry faeces, lb*
9–10/10/56	21·7	10·6	49·6	18·1	70·7
10–11/10/56	22·9	7·2	57·3	12·6	81·0
11–12/10/56	19·1	8·1	58·1	14·7	78·8
12–13/10/56	20·6	13·2	55·5	10·7	69·2
13–14/10/56	23·5	8·5	58·3	9·7	74·5
Period II					
24–25/10/56	18·9	15·7	50·7	14·7	84·4
25–26/10/56	25·0	12·5	47·5	15·0	91·8
26–27/10/56	22·1	11·5	53·1	13·3	87·0
27–28/10/56	25·1	10·2	49·5	15·2	91·9
28–29/10/56	22·8	13·5	50·9	12·8	96·6
29–30/10/56	24·8	12·8	47·6	14·8	90·3

The results of the dry matter determinations given in *Table 2* show marked differences between samples. These could be due to a number of

causes. In the first place, some may be due to sampling errors; the 1 000 g sub-sample being a very small proportion of the dung collected, particularly of the large bulk collected at 7 a.m. Similarly, the differences may be due to weather conditions, but although the 4 p.m. collection of dung was often dried on the outside of the pats, the percentage dry matter does not appear to have been affected greatly. Alternatively, the differences could be real and could be due to variations in the moisture content of the dung produced by all the animals or to variations in the proportions of high and low dry matter faeces produced by different animals. The young animals appeared to produce higher dry matter faeces but it is not known whether the relatively small quantity of dung produced by the calves has biased the results to any extent.

Table 2. Percentage dry matter for the samples of dung for each period, and the total daily production of wet faeces

	Percentage				
Period I	*10 a.m. to 4 p.m.*	*4 p.m. to 7 p.m.*	*7 p.m. to 7 a.m.*	*7 a.m. to 10 a.m.*	*Total weight of wet faeces, lb*
9–10/10/56	19·6	19·1	19·1	19·2	367
10–11/10/56	19·3	19·0	19·1	19·2	423
11–12/10/56	18·6	18·6	17·9	17·8	436
12–13/10/56	17·3	16·5	16·4	17·0	416
13–14/10/56	17·8	18·0	18·0	16·6	418
Period II					
24–25/10/56	18·0	18·4	17·0	16·5	488
25–26/10/56	17·1	17·3	18·5	18·2	512
26–27/10/56	18·2	18·4	20·3	17·2	455
27–28/10/56	18·4	17·6	18·3	17·2	509
28–29/10/56	17·6	16·5	18·2	16·7	549
29–30/10/56	17·3	17·4	17·3	17·4	521

The inclusion of young stock in the herd has also influenced the distribution of dung pat sizes. The data in *Table 3*, which gives the distribution of dung pat sizes in 200 g classes of wet weight, should have shown normal distributions for each collection time, but the existence of various age groups has caused abnormal distribution. It was for this reason that the weighing of individual pats was discontinued after the first 24 hours.

Table 3. Percentage distribution of dung pat weights for one day's collection

Class, g	*10 a.m. to 4 p.m.*	*4 p.m. to 7 p.m.*	*7 a.m.*	*10 a.m.*
0–200	8·2	23·8	10·8	9·8
2–400	32·9	26·2	9·2	21·6
4–600	27·4	23·8	20·8	25·4
6–800	23·3	21·4	16·7	19·6
8–1 000	4·1	4·8	9·2	13·7
10–1 200	2·7		13·3	5·9
12–1 400	1·4		10·0	
14–1 600			2·5	2·0
16–1 800			2·5	2·0
18–2 000			1·7	
Over 2 000			3·3	

In spite of the complication of the various age groups, the data for the number of dung pats collected provide useful information on the habits of the animals. A summary of the data is given in *Table 4*. These results show that, under a particular grazing management, the mean dung pat size for a specific time interval is remarkably consistent from day to day, but that there can be considerable differences between various time intervals. An explanation for this phenomenon is that dung pat sizes are affected appreciably by the habits of the grazing animals.

Table 4. Summary of mean wet weights in lb and numbers of dung pats produced

Category	*Period I*	*Period II*
Mean wet weight of pats 10 a.m. to 4 p.m.	1·2±0·14	1·5±0·10
Mean wet weight of pats 4 p.m. to 7 p.m.	0·9±0·10	1·4±0·09
Mean wet weight of pats 7 p.m. to 7 a.m.	1·7±0·14	2·2±0·12
Mean wet weight of pats 7 a.m. to 10 a.m.	1·2±0·14	1·5±0·05
Mean total number of pats per day	295±17	287±11

Full-time records of the animals' grazing behaviour were not kept during the dung collection periods, but studies with the adult animals of the same herd and on the same paddock have been recorded (HARKER *et al.* 1953–7). Brief observations, however, indicated that the grazing of the animals conformed to the normal pattern for this type of pasture and for the management imposed. During the first collection phase, grazing started about 6.30 a.m. and carried on until 10 or 11 a.m.; in the mid-day period the grazing pattern was variable—some grazing and some rumination occurring. In the afternoon, a high proportion of the time was spent standing under the shade of trees and, in the evening, grazing started actively around 4 p.m. and continued until 7.30 p.m. At night, some grazing occurred around midnight but most of the time was spent lying down. During the second phase, grazing followed a similar pattern throughout the hours of daylight, but was more intense; at night the animals spent almost all of their time lying down, whilst they began to stand up about 6.30 a.m. and started grazing intensively as soon as they were put into the day paddock. Relating the dung pat size data to this information on the animals' grazing habits, it is apparent that whilst the animals were grazing actively the dung pat sizes were smaller and, conversely, when the animals were mainly resting, the mean dung pat size was greater.

A comparison of the data for total dung production shows that more dung was produced during the second period. This may be a result of the animals eating more under the system of night paddocking or it may be due to a decrease in the digestibility of old material. Thus, if the mean food intake for the herd was 230 lb of dry matter per day, a change from 68 per cent to 62 per cent total digestible nutrients could account for the whole of the change in the faeces output. As, however, any changes should be slow, the differences, if any, in digestibility should not affect a comparison of the pattern of dung distribution throughout a day, although a comparison of total weight of dung produced may not be valid.

To avoid the complication of changing digestibility, the collection periods should be relatively close together. If, however, the periods are too close, the animals may not have time to change their behaviour to suit any changes

in management. Independent observations (HARKER *et al.* 1953–7) indicate that the animals change their grazing pattern very quickly. It was for this reason that only one day was allowed between collection periods III and IV.

(B) Results for collection periods three and four

It will be noted that the major change in the design of this part of the trial is that dung was collected twice daily; one collection of the dung produced during the ' day ' and the other of the dung produced during the ' night '. The accuracy of collection should also have increased since the animals were moved to a new paddock at a specific time irrespective of whether or not the dung had been collected completely from the old paddock before the move. The counting of pats, weighing total bulk and sampling for dry matter remained unchanged. *Tables 5* and *6* give a summary of the results for the third and fourth collection periods respectively.

Table 5. Summary of dung production data for period III

Date	*Dung dropped during ' day '* (*7 p.m.*)			*Dung dropped during ' night '* (*7 p.m. to 7 a.m.*)		
	Wet wt lb	*Dry wt lb*	*Number of pats*	*Wet wt lb*	*Dry wt lb*	*Number of pats*
4–5/2/58	250	48·3	207	223	43·3	86
5–6/2/58	203	38·2	166	218	44·3	106
6–7/2/58	205	39·1	139	247	48·5	111
7–8/2/58	218	43·3	137	241	45·2	114
8–9/2/58	198	36·4	161	241	45·0	119
9–10/2/58	227	42·6	172	234	43·4	83

Table 6. Summary of dung production data for period IV

Date	*Dung dropped during ' day '* (*8 a.m. to 4 p.m.*)			*Dung dropped during ' night '* (*4 p.m. to 8 a.m.*)		
	Wet wt lb	*Dry wt lb*	*Number of pats*	*Wet wt lb*	*Dry wt lb*	*Number of pats*
11–12/2/58	128	25·9	117	287	55·6	130
12–13/2/58	147	28·3	112	288	55·3	139
13–14/2/58	152	29·6	100	307	59·5	152
14–15/2/58	158	30·5	124	317	63·4	144
15–16/2/58	149	30·1	117	298	60·5	156
16–17/2/58	132	27·7	99	266	55·6	151

The results for collection period three (*Table 5*) indicate that, if the animals are given twelve hours grazing and twelve hours resting, slightly more than half the dung is dropped during the nightly twelve hours rest. Except for the first day, this is true for each comparison of day and night production. The exception could be due to the disturbance of first day collecting or to incomplete clearing of the paddock prior to the trial commencing. If, however, the latter were the cause, a higher percentage dry matter in the faeces would be expected and this was not the case.

The results from collection period four (*Table 6*) also show that the rate of excretion of dung was relatively constant throughout the 24 hours. During the period, the animals were allowed only eight hours grazing and during that time approximately 33 per cent of the dung was dropped and, except

for the first day, the results were fairly consistent. This low result on the first day could have been due to the animals failing to settle down quickly to the new management conditions, but the result of the last day is almost as low, so that the difference could be part of a natural fluctuation.

DISCUSSION

The results from all four collection periods show consistently that the rate of dung production throughout the day by a herd of cattle is fairly constant. This is in marked contrast to the rate of food intake. During the first period, approximately a third of the total grazing occurred during the night; a time when no grazing was allowed in the other three collection periods. Similarly, in the fourth collection period the animals were denied grazing during the normally active periods of early morning and late evening, and had to concentrate all their grazing into eight hours. It must be remembered, however, that these results were obtained when there was plenty of available grazing, and restricting the grazing to eight hours did not appreciably affect the volume of dung produced. Different results might have been obtained under poor grazing conditions.

Although variations in the grazing habits of the animals do not seem to affect the distribution of dung by weight, they do appear to have an affect on the number of dung pats produced. Taking averages over each collection period 13, 15, 14 and 14 dung pats per hour respectively were dropped during daylight grazing, whilst at night 11 per hour were dropped if the animals were free to graze and only 9 were dropped in both 12 hour nights and the 16 hour nights when no grazing was allowed. The practical significance of this is that it would be dangerous to assume an average weight per pat and base all calculations on the number of times the animals defaecated.

CONCLUSIONS

(1) The data indicate that, for most practical purposes, if the food supply is adequate, the rate of faeces production is constant throughout the 24 hours and is not related to the distribution of food intake.

(2) Under the systems of management studies, the animals dropped larger dung pats whilst they were resting than when they were grazing or walking about.

(3) This type of trial is open to many errors; some of these can be avoided as follows:

(a) by making the minimum number of collections
(b) by collecting from the ground rather than from faeces bags
(c) by collecting all faeces rather than a sample
(d) by continuing the trial over a number of days.

(4) For this herd of mixed age groups, the mean wet weight of dung produced varied from 18·8 to 27·5 lb per head per day.

SUMMARY

The dung produced by a small breeding herd was collected when the animals were under three different management conditions, in order to

assess the distribution of dung throughout the day. The results are discussed in relation to management conditions and grazing behaviour. They indicate that the rate of dung production is not markedly influenced by the times the animals graze.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance rendered in the field and in the laboratory by members of the Animal Health Research Centre staff, and the permission of the Director of Veterinary Services and Animal Industry to publish this paper.

(*Received September 1959*)

REFERENCES

HARKER, K. W., TAYLOR, J. I. and ROLLINSON, D. H. L. (1954). 'Studies on the habits of Zebu cattle, I—Preliminary observations on grazing habits'. *J. agric. Sci.* **44,** 193–8

HARKER, K. W., TAYLOR, J. I. and ROLLINSON, D. H. L. (1956). 'Studies on the habits of Zebu cattle, V—Night paddocking and its effect on the animal'. *J. agric Sci.* **47,** 44–9.

HARKER, K. W. *et al.* (1953–7). 'Grazing behaviour studies'. Animal Health Research Centre: unpublished data

ROLLINSON, D. H. L., HARKER, K. W., TAYLOR, J. I. and LEECH, F. B. (1956). 'Studies on the habits of Zebu cattle, IV—Errors associated with recording techniques'. *J. agric. Sci.* **47,** 1–5

WILLIAMS, A. E. B. and BUNGE, V. A. (1948). 'Cattle observations'. Agricultural Dept, Serere, Uganda: unpublished data

Soya Beans in a Mechanized Farming System in Tanganyika

A. K. Auckland

Botanist, Ministry of National Resources, Tanganyika

The Overseas Food Corporation was established by the Overseas Resources Development Act in 1948. One of the duties charged to the Corporation was to secure ' the large scale production of groundnuts, together with crops rotational therewith or ancillary thereto, in Colonial territories in East and Central Africa, and the marketing thereof ' (Overseas Food Corporation *Report 1948–49*).

One of the areas in which the ill-fated ' Groundnut Scheme ' was developed was at Nachingwea in the Southern Province, Tanganyika. Nachingwea is situated about 80 miles inland from the coastal port of Lindi, at an elevation of 1 400 ft above sea level.

The climate is characterized by a single rainy season and a long dry season. The rains normally begin in late November and continue until the end of April to mid-May. Seasonal rainfall totals (i.e. from 1 November to 29 May) vary considerably, from 20·6 to 45·4 in. with a mean of 32·7 in. Mean monthly maximum temperatures vary between 82·3°F (June) and 92·2°F (February); corresponding minimum temperatures between 59·6°F (July) and 71·0°F (December). The mean monthly relative humidity varies from 66 (October) to 88 (April) per cent at 09.00 hours: and 36 (August and September) to 68 (March) per cent at 15.00 hours.

The natural vegetation in the area is ' Miombo ' (*Pseudoberlinia–Brachystegia* woodland). *Combretum*, another tree genus, is also widely represented in places, and in certain portions of the ' Miombo ', bamboo (*Oxytenanthera abyssinica*) forms a dense understorey.

CROP HISTORY OF THE GROUNDNUT SCHEME IN NACHINGWEA

Clearing of the land had been begun by contractors in November 1947, and was in progress when the scheme was taken over by the Overseas Food Corporation, but it was not until the 1951 season that any large scale plantings were carried out.

Figure 1 shows acreages of the main crops planted in the area from 1951 to 1959.

In the 1951 season most of the land, as envisaged, was planted to groundnuts, with maize as the next important crop. Three per cent of the land was planted to soya beans and 3 per cent of the land to ' other crops '. The ' other crops ' at this stage included sunflower, millet, cotton and cowpeas.

By the 1952 season, more land had been cleared. Once again, a large acreage of groundnuts was grown in comparison with other crops. This brought considerable difficulties as far as planting and harvesting were

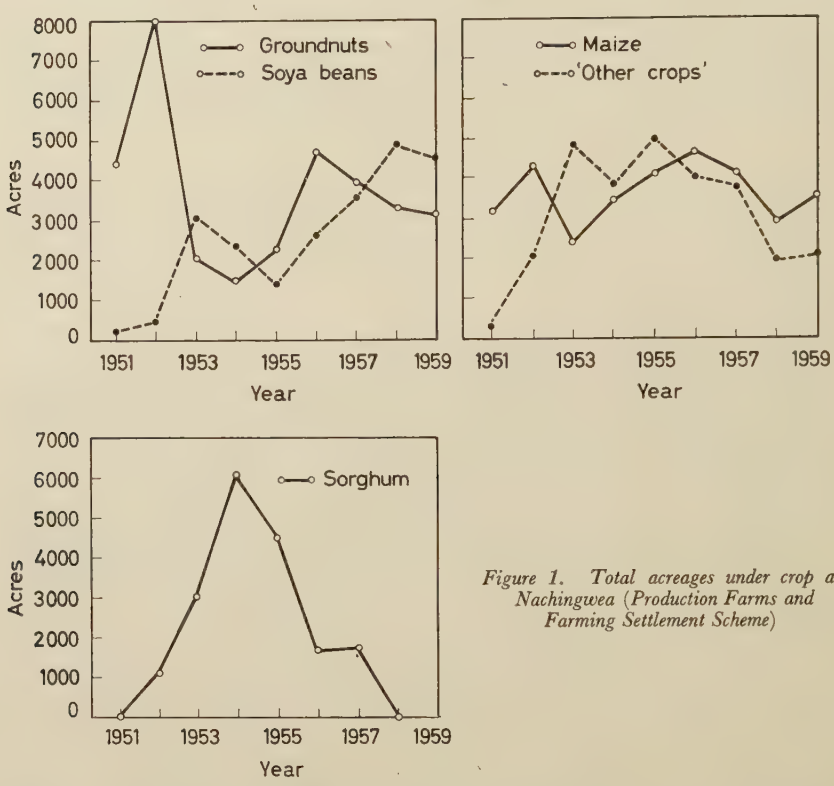

Figure 1. Total acreages under crop at Nachingwea (Production Farms and Farming Settlement Scheme)

concerned. The large acreage perforce had to be planted over an extended period of time, and also required the employment of a large machine and labour force. If plantings were late, the optimum number of days required for the maturity of groundnuts was reached after the topsoil had become hard at the end of the rains. Lifting of the goundnuts had therefore to be carried out rapidly before the ground hardened, necessitating a large labour force. With late plantings, yields were low due to the necessity for untimely harvesting. With maize, soya beans and other crops whose seeds were borne above ground, the position was easier, as it was possible to spread the harvesting and planting, and labour problems were less acute. With late plantings of these crops, yields were naturally lower, but there was considerable available moisture in the lower levels of the soil after the rains had finished, and yields were not so badly affected as with groundnuts.

At this stage therefore, with groundnuts forming 51 per cent of the total acreage under crop, and maize 27 per cent, an unbalanced system of farming was created due to the long planting season brought about by a small machine and labour force.

A short-term groundnut variety, Natal Common, was grown during this season. It was upright in habit and suitable for combining after lifting and windrowing, but was badly affected by rosette disease. As a result of this disease, yields were low and many acres had to be ploughed in. It was at the end of this season that the optimistic vision of the large scale production

of groundnuts to relieve the fat shortage in the United Kingdom began to be treated with scepticism.

Due to the failure of groundnuts in the 1952 season, the next two seasons saw a sharp fall in acreages planted to this crop. In a desperate attempt to find profitable crops suitable to the area, ' other crops ' formed the largest percentage of acreage under crop. The ' other crops ' tried at this stage were cashew, tobacco, castor, millets and many types of legumes.

In 1953 there was a large increase in the acreage of sorghum, and soya beans had increased to 20 per cent of the total acreage. The soya bean variety Dixie was grown at this stage. It was a combinable type, but was very uneven in ripening and particularly susceptible to shattering. There were large losses due to the latter cause. The best field yield was 835 lb/acre, but the average was only 289 lb/acre.

In the 1954 season, sorghum was the most important crop. The variety Dobbs gave good yields and could be combined easily. A high government support price was then paid for sorghum, including the Dobbs type grown. The acreage of groundnuts reached its lowest, and the acreage of soya beans had been reduced, due to the unsuitability of the variety.

After the initial failure of the groundnut variety Natal Common, work had been carried out in the Research Department to find a rosette-resistant variety. In 1954 it was discovered that the variety Asirya Mwitunde if grown in isolation showed a field resistance to rosette (Evans, 1956). The growing of this single variety throughout the Nachingwea area gave very adequate control of the disease.

Once again the possibility of growing groundnuts on a large scale was envisaged, and this marked the turning point of the Scheme. In the 1955 season the acreage under groundnuts was increased and in 1956 when more Asirya Mwitunde seed was available, groundnuts once again became the most important crop in the area.

The acreage of soya beans decreased further in 1955, due to the unsuitability of the variety, and the support price paid for sorghum. Hernon 237, a soya bean variety from Southern Rhodesia, giving higher yields and far less susceptible to shattering than Dixie, was introduced at this stage. With the advent of this variety, soya bean acreages began to increase rapidly.

The government support price paid for sorghum was taken off, and this crop became almost uneconomical to grow. Devastating attacks of American bollworm in two successive years were unworthy of chemical control measures due to the low value of the crop. The bollworm attacked the grain of sorghum in the milky stage. Difficulty was experienced in disposing of the crop in 1957, and considerable damage by storage pests occurred due to the fact that the grain of the varieties grown had a non-corneous endosperm. As a result of these factors acreages of sorghum decreased, until by the 1958 season no sorghum was grown in the area.

Throughout the history of the Scheme maize has maintained a steady level in acreage. Good yields have been obtained throughout, and improved yields were obtained in later years from rust-resistant maizes produced by the Plant Pathologist.

In 1957 it was realized that soya beans could be an important production crop and a decision was made to increase the acreage appreciably in 1958,

because of its high yield, low cost of production and the higher premium price obtained for the type of beans produced. In 1958 maize and groundnuts took an almost equal second place to soya beans. The acreages grown to ' other crops ', at this stage largely consisting of sesame and permanent cashew, had decreased rapidly due to the present suitability of the three main crops.

A stable agricultural system has been established, with three important crops grown in a rotation of groundnuts, maize and soya beans respectively. Soya beans are now recognized as the most important crop in the area—in fact it might now be said that the ' Groundnut Scheme ' with ' crops rotational therewith or ancillary thereto ', has become a ' Soya bean Scheme ' with ' crops rotational therewith or ancillary thereto '.

PRESENT ORGANIZATION OF THE AREA

The undertakings of the Overseas Food Corporation in Tanganyika were transferred in March 1955 to the Tanganyika Agricultural Corporation. The transferred undertakings consisted of a scheme described in the White Paper presented to Parliament in January 1951 (*Command 8125*) as ' a scheme of large scale experimental development to establish the economics of clearing and mechanized or partly mechanized agriculture in tropical conditions '.

The scheme in Nachingwea now consists of 14 Production Farms run on an estate basis, varying in size from about 550 acres to 1 000 acres. An area of cleared land has been set aside and used as a Farming Settlement Scheme (Cocking and Lord, 1958), with a view to ' ensuring the evolution of the African Yeoman Farmer, from the peasant to the final stage of owning his own land of sufficient area to ensure independence and a reasonable standard of living ' (Tanganyika Agricultural Corporation *Report, 1955*). The Farming Settlement Scheme is under European management and in the current year there are about 80 African tenants each farming a holding of about 15 acres under crop with a similar acreage of fallow. Considerable importance is attached to the Farming Settlement Scheme and it is believed that the scheme ' if successfully developed, established and expanded, should contribute substantially to the evolution of a sound economy in the territory, an economy which is, at present, based preponderantly on agriculture and, subject to any significant mineral discoveries that may be made, is likely to remain so in the foreseeable future ' (Tanganyika Agricultural Corporation *Report, 1955*).

ECONOMICS OF CROP PRODUCTION

Tables 1, 2, 3 and *4* are self-explanatory in illustrating the economic superiority of soya beans to other crops in the area.

(*a*) *Yields*

The increase in yields obtained from soya beans in recent years is due to the suitability of the variety and improved methods of production. The increase in yields of Hernon 237 over the years may be attributed to the natural selection of higher yielding types within the variety, and the elimination of shattering types by the fact that they are left unharvested. The

general decrease in crop yields in 1958 is attributed to the exceptional shortage of rain during this year.

Certain individual tenants on the Farming Settlement Scheme have produced groundnut and soya bean yields in excess of the highest yields recorded on Production Farms, but the overall average is normally lower than the average on Production Farms. In the poor rainfall year of 1958 the average on the Farming Settlement Scheme was higher than the Production Farm average. These high yields on the Farming Settlement Scheme may be attributed to the ideal populations obtained from hand planting, and the comparatively small losses of crop due to hand harvesting. Yields of maize on the other hand are much lower on the Farming Settlement Scheme than on Production Farms, chiefly because with this crop it has been difficult to convince the African farmer that high populations give higher yields than his traditional method of planting three seeds per hole at wide intervals. The exceptionally low average yield for maize on the Farming Settlement Scheme in 1958 was due to defaulting tenants who either sold their maize outside the scheme, or failed to complete harvesting.

Although the yields of maize on Production Farms are higher than those of either soya beans or groundnuts, the value of the crop is not as high, due to the price differential and the fact that a great deal of low output labour is involved in its harvest.

Table 1. Yields of main crops on the Farming Settlement Scheme in lb/acre

1. Highest individual holding yield

Crop/year	1954	1955	1956	1957	1958
Groundnuts	510	1 885	1 509	1 044	1 087
Maize	1 297	2 108	1 655	2 111	797
Soya beans	892	1 384	1 433	2 048	1 215

2. Average yield over the whole Scheme

Crop/year	1954	1955	1956	1957	1958
Groundnuts	358	794	657	464	329
Maize	560	535	575	463	36
Soya beans	457	700	808	928	629

Table 2. Yields of main crops on Production Farms in lb/acre

1. Highest farm yield

Crop/year	1955	1956	1957	1958
Groundnuts	1 430	1 062	903	1 006
Maize	1 700	1 866	2 460	2 101
Soya beans	1 195	1 099	1 426	975

2. Average yield over all farms

Crop/year	1955	1956	1957	1958
Groundnuts	808	680	626	689
Maize	1 573	1 465	1 698	1 428
Soya beans	849	830	1 003	513

(b) Prices

There has been a steady increase in the price obtained for soya beans in comparison with a sharper decrease in prices for groundnuts. With fluctuating crop prices, however, it is possible that there may be a future reversal of the present situation.

Table 3. Crop prices paid to African tenants in £ per ton

Crop/year	1956	1957	1958
Groundnuts	58·00	52·70	48·00
Maize	12·50	14·00	16·15
Soya beans	33·00	37·00	38·00

NOTE: The Corporation may have obtained more or less than these prices when the crop was finally sold.

(c) Costs of production

Table 4. Costs of production of three main crops per acre in 1956 in East African shillings (Production Farms—See LORD, *1956)*

Operation	*Groundnuts*			*Maize*			*Soya beans*		
	Labour	*T.T.*	*Total*	*Labour*	*T.T.*	*Total*	*Labour*	*T.T. and comb.*	*Total*
Ploughing	1·0	16·0	17·0	1·1	19·6	20·7	1·2	20·9	22·1
Planting	0·8	7·1	7·9	0·9	5·8	6·7	0·6	6·6	7·2
Weeding	9·8	8·9	18·7	3·9	5·5	9·4	7·6	2·8	10·4
Stooking	19·2	11·2	30·4	7·8	0·8	8·6	1·1	0·1	1·2
Picking/ combining	25·3	29·4	54·7	9·2	5·7	14·9	2·2	30·3	32·5
Decorticating/ shelling	12·6	19·8	32·4	3·8	11·3	15·1	1·7	4·0	5·7
Dispersal of crop residue	0·6	0·8	1·4	0·7	0·6	1·3	0·1	0·2	0·3
Total	69·3	93·2	162·5	27·4	49·3	76·7	14·5	64·9	79·4
Seed			27·5			3·1			11·1
Fertilizer			18·1			44·7			17·3
Sacks			10·0			17·0			9·8
Handling			3·7			6·7			3·9
Total expenditure			221·8			148·8			121·5
Total income			383·7			249·5			286·5
Margin over direct costs			161·9			101·3			164·6

T.T. denotes tractor labour: Comb. denotes combine.

The low cost of production of soya beans in comparison with groundnuts is the prime factor in making it the most important economic crop in the area. As can be seen from *Table 4*, the great saving incurred with soya beans is in the lower labour costs. The labour requirements of soya beans on Production Farms are approximately 7 man-days per acre in comparison with 38 and 14 man-days per acre for groundnuts and maize respectively.

SOYA BEAN CULTIVATION

Soya beans are normally planted in early January to early February, after the groundnuts and maize are established, but there is now a tendency for soya beans to replace maize in the sequence of crop planting. On Production Farms the beans are planted on the flat in 28 in. rows, and drilled to a depth not greater than 1·5 in., with 2 in. between plants. Where economic returns will result, 100 lb/acre of single superphosphate is applied with the seed. On the Farming Settlement Scheme, soya is hand-planted on 34 in. ridges, with two rows per ridge at 2 in. spacing between plants. One or two weedings per season are necessary.

In some years, considerable difficulty is experienced from the ' capping ' of the soil. If planting on a damp or wet soil is followed by bright sun for a period of days, the red sandy loams on which most of the beans are planted form a hard crust. The germinating beans are unable to penetrate this crust or ' cap ', and the resultant stand may be poor. Rainfall immediately after planting is equally dangerous if followed by bright sunny days. Ideal stands are obtained if damp dull days occur during the planting season (*Figure 2*).

Figure 2. An ideal stand of soya beans on the Farming Settlement Scheme at Nachingwea

Once the crop has germinated and is through the soil, there is little cause for worry, and given good rains, one can expect a good crop at harvest. A certain loss of stand is caused by the depredations of termites, but the variety Hernon 237 is accommodating and can compensate for reasonable gaps by profuse branching. The crop normally matures in about 121 days after planting, but this period may be shortened if the season is a dry one. Harvesting begins in May, and is done by direct combining on Production Farms and hand-stooking followed by combining on the Farming Settlement Schemes.

Soya beans in this area have no serious pests or diseases. *Cercospora* leaf spot usually appears in the later stages of growth, but seems to assist the required defoliation prior to harvest. When soya beans were first introduced into the area, inoculation of the seed with bacteria was necessary for nodulation, but there are now sufficient bacteria present in the soils of the area to make inoculation unnecessary.

SOYA BEAN BREEDING

The importance of soya beans in the area, and their potential importance in the territory as a whole, were realized in 1955, and a breeding and selection programme was initiated with the aim of producing new higher yielding varieties suitable for the area (AUCKLAND, 1956 *et seq.*).

Numerous varieties from various parts of the world had been tried experimentally, but for most varieties the day length and climatic conditions in this area were unsuited to their well-being. Only eight varieties met with any degree of success. The characteristics of these varieties are shown in *Table 5.*

Table 5. Characteristics of soya bean varieties

Variety	*Source*	*1957 yield lb/acre*	*Habit*	*Days to maturity*	*Seed colour*
Malaya	*Nigeria*	1 996	*Indeterminate*	121	*Yellow*
Hernon 237	*S. Rhodesia*	1 990	*Indeterminate*	121	*Yellow*
Light Speckled	—	1 725	*Determinate*	107	*Yellow*
R.184	—	1 555	*Determinate*	107	*Yellow*
MIS28EB	*Indonesia*	1 532	*Indeterminate*	118	*Yellow*
CNS	*U.S.A.*	1 476	*Intermediate*	115	*Brown*
Benares	*Nigeria*	1 391	*Indeterminate*	121	*Yellow*
Glycine Ruggett	—	1 329	*Determinate*	107	*Black*

NOTE: Yields were obtained on experimental plot scale.

The varieties MIS28EB, Hernon 237, Malaya and Benares have all been grown on Production Farms, but Hernon 237 was found to be the most suitable on the whole. A certain amount of MIS28EB is still grown, because of its shorter growing period; this enables a farmer with a large acreage of soya beans to stagger both the harvesting and planting season to a limited degree. These varieties are fairly satisfactory, but sometimes produce very rank growth, which often lodges badly and is difficult to harvest. They have the ' indeterminate ' habit of growth, with numerous branches borne at a wide angle to the main stem and as many pods on the side branches as on the main stem. Hernon 237 is in fact used in Southern Rhodesia as a forage variety.

Determinate varieties have fewer branches than indeterminate ones and the branches are borne at a narrow angle to the main stem. Most of the pods are clustered thickly on the main stem and there are usually more pods per flower stalk than in the indeterminate varieties. The determinate varieties have a shorter period of maturity and are smaller than the indeterminate varieties. Although the determinate varieties are most efficient plants (especially Light Speckled and R184) they are unsuitable for combining due to the pods being borne close to the ground.

Ideally, a tall variety with a determinate habit and pods borne at least 6 in. above soil level would be easier to harvest by machine. For hand harvesting by the African farmer, high yield and non-shattering are the only qualifications necessary. With these aims in mind, various intervarietal crosses were made in 1955, and by out-of-season watering during the bulking generations, F7 lines were ready for testing in strain trials in the 1959 season. Numerous strains of varying habits and maturity dates have

been obtained, and yields have shown up to a 68 per cent increase on the standard variety Hernon 237.

The issue of new soya bean varieties yielding 50 per cent higher than Hernon 237, and being more suitable for combine harvesting, would contribute substantially to the ultimate success of the farms in the area, and also may have something to contribute to agriculture in the territory as a whole. It is not too optimistic a hope that these varieties will be forthcoming.

SUMMARY

A history of the fluctuations of crop production in a system of mechanized farming at Nachingwea in Southern Tanganyika has been outlined. The original place of groundnuts as the most important crop in the area has now been taken by soya beans. The agricultural and economic reasons for the importance of soya beans are explained. The issue in the near future of new higher yielding soya bean varieties suitable for combine harvesting is expected to contribute substantially to the economic success of the scheme.

ACKNOWLEDGEMENTS

The author wishes to thank the Director of Agriculture, Tanganyika, and the Chairman of the Tanganyika Agricultural Corporation for permission to publish this paper; Mr W. P. Cocking, Dr A. C. Evans and Mr D. H. Hancock for useful advice and criticism in the preparation of the paper; and Mr R. F. Lord for permission to publish *Table 4*.

(*Received August 1959*)

REFERENCES

Auckland, A. K. (1956 *et seq.*). *Rep. Dep. Agric. Tanganyika*

Cocking, W. P. and Lord, R. F. (1958). 'The Tanganyika Agricultural Corporation's Farming Settlement Scheme'. *Trop. Agriculture, Trin.* **35,** 85–101

Evans, A. C. (1956). 'A study of a rosette resistant groundnut variety, Asirya Mwitunde', *E. Afr. agric. J.* **22,** 27–31

Lord, R. F. (1956). 'Tanganyika Agricultural Corporation, Nachingwea, Farming Results. Part II'. (Unpublished report)

Overseas Food Corporation 1947–1954, *Annual Reports*

Tanganyika Agricultural Corporation 1955 *et seq.* *Annual Reports*

Seed Fertility of 'Gros Michel' Bananas

K. Shepherd

Cytogeneticist, Regional Research Centre,
Imperial College of Tropical Agriculture, Trinidad, W.I.

Haploid pollination of triploid 'Gros Michel' bananas remains as the only established practical method of producing new varieties of that crop. While the output of seeds from such pollinations is so small as to impose a major limiting factor on the breeding programme, it is also so variable as to invite careful study. In an earlier account (Shepherd, 1954) the author summarized the more significant findings from experiments and banana breeding records up to August 1951. The present intention is to amplify this account with more recent data, again both from experiments and from routine records. Unless otherwise stated, all pollinations were done at Bodles, Old Harbour, Jamaica.

It was established previously that the seed yield of a 'Gros Michel' bunch was determined by, among other things, its location, its number of 'hands' and its date of emergence, the last for reasons which were not at all clear. Since 1952, an increasing variety of pollen sources has been utilized and, though all fall within the diploid species *Musa acuminata*, it will be shown below that they are not equally successful. Because of this, and the number of other variables, particular caution is necessary in the interpretation of routine records. Conclusions on the effects of single factors, or their interactions, have only been drawn in relation to the degree of definition of other, irrelevant factors.

VARIATION IN TIME

The effect of season on seed yield was previously noted, especially the remarkable correspondence of month to month yields at the early breeding stations at Potosi and Brimmer Hall. From Bodles Field IV, of about 800 stools, records are available for more than five years of continuous operation, although with an overlapping sequence of pollen parents. The trends of bunch sizes and seed yields in *Figure 1* have been smoothed by taking three months' running averages, rather than single months' details.

There would seem to be two peaks of bunch size in every year, a narrow one about January–February and a broader one roughly embracing the period June to September. Despite the fact that ample irrigation water was available, it is tempting to believe that these periods of unusual well-being followed the main periods of natural rainfall in this part of Jamaica. The annual rhythm is confirmed by serial correlations of monthly averages during the period January 1954 to December 1956 (method after Quenouille, 1952). 1953 data were not included because, in the young stages of a field, bunch sizes and seed yields may be determined by other than periodic factors (see below). Averages were compared at intervals of one month,

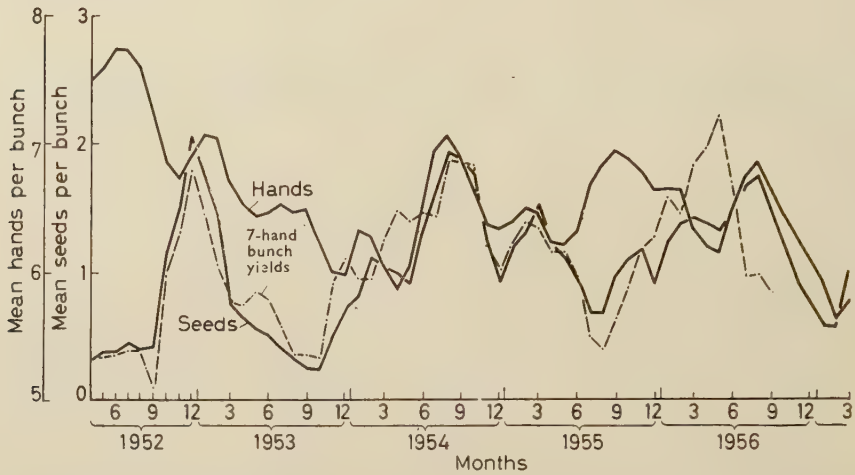

Figure 1. Trends for monthly means of hands and seeds per bunch (solid lines) and seeds per 7-hand bunch (broken line) over five years in Bodles Field IV

two months, etc., up to one year and the correlation coefficients are shown in *Table 1*. Significant positive correlations emerged for adjacent months, as was of course expected, and also for the same month in successive years. There was a significant negative correlation for averages at four-monthly intervals.

Now, since seed yields vary with bunch size, at least for samples taken over a limited period and area (SHEPHERD, 1954, and see below), one would expect the monthly averages for seeds per bunch to parallel those for hands. It is evident from *Figure 1* that this was only sometimes true. The correlation coefficient for mean seeds and mean hands is indeed significantly positive for the months of 1954 to 1956 ($r=0{\cdot}457$, $p<0{\cdot}01$); but there are no significant serial correlations of mean seed yields at intervals up to one year. The divergences are understood on examination of the mean

Table 1. Bunch sizes and seed yields from Bodles Field IV 1954–56—serial correlations of monthly means

Interval (months)	*Comparisons*	*Bunch size*		*Seed yields*	
		*r**	*p†*	*r**	*p†*
1	35	+0·4474	<0·01	+0·2031	*NS*
2	34	−0·0065	*NS*	+0·0512	*NS*
3	33	−0·2138	*NS*	+0·1406	*NS*
4	32	−0·4592	<0·01	−0·1211	*NS*
5	31	−0·2597	*NS*	−0·1249	*NS*
6	30	+0·1517	*NS*	+0·0662	*NS*
7	29	+0·0517	*NS*	+0·0041	*NS*
8	28	−0·1919	*NS*	−0·1760	*NS*
9	27	−0·1023	*NS*	−0·2208	*NS*
10	26	−0·1462	*NS*	−0·1627	*NS*
11	25	+0·2543	*NS*	−0·3160	*NS*
12	24	+0·6131	<0·01	−0·2682	*NS*

* Corrected by the addition of $1/n$.

† Based on $t_{(n-2)}=r(n-2)^{1/2}/(1-r^2)^{1/2}$. NS = not significant.

seed yields of bunches of a selected standard size (seven hands), also included in *Figure 1*. It can be seen that the fertility of even such standard bunches is subject to considerable and irregular fluctuations in time. Seed yields are evidently then the resultant of two forces, one apparently seasonal and determining the level of bunch sizes, the other non-seasonal and determining the general level of fertility within sizes of bunch. They are encouragingly high only at those uncommon times when both forces are at a peak.

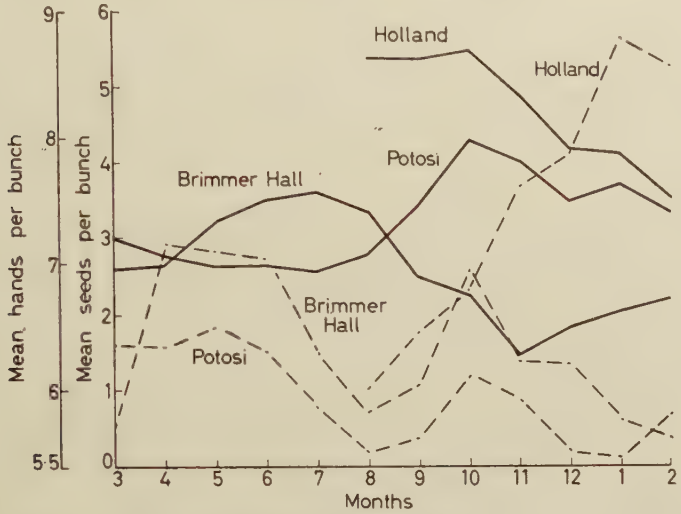

Figure 2. Trends for monthly means for hands per bunch (solid lines) and seeds per bunch (broken lines) for three Jamaican stations in 1948–49

The independence of these factors is emphasized by the averages shown graphically in *Figure 2*. The averages for seeds per bunch were published previously (SHEPHERD, 1954), but those for hands per bunch have been added and reveal that the similarity of the seed yield trends for the stations at Potosi and Brimmer Hall was achieved despite a gross disparity in the trends for bunch size. Furthermore, while the seed yields at Holland were very different in pattern, rising steadily as at Bodles in the early stages, the bunch sizes were closely parallel to those of nearby Potosi for the few months recorded. In fact, Holland was a new planting (R. E. OSBORNE, personal communication) and behaves in what has only recently been recognized as a typical manner (see below).

COMPARISONS BETWEEN FIELDS AND AGES OF FIELDS

In comparing the performance of different fields, the main difficulty to be overcome is that they are planted successively and come into bearing at various seasons and at intervals of several months if not some years. They may also be exposed to slightly different environments or techniques of management and they will almost certainly be employed for different pollen parents, for which no precise allowance can easily be made. The effective choice is between comparing fields of different ages at the same

time and comparing fields of the same age at different times and seasons. Since the effect of seasons has already been expounded it would be more instructive for the present to choose the second alternative, as has been done in *Table 2.*

Table 2. Six Bodles fields compared for mean hands per bunch and mean seeds per bunch for the first six quarterly periods of their bearing life and for their whole bearing life

Quarter	IV		V		VII		VIII		IX		X	
	$\bar{H}$	$\bar{S}$	$\bar{H}$	$\bar{S}$	$\bar{H}$	$\bar{S}$	$\bar{H}$	$\bar{S}$	$\bar{H}$	$\bar{S}$	$\bar{H}$	$\bar{S}$
1	6·81	0·35	7·73	0·32	7·41	0·75	8·25	1·70	8·39	1·04	8·82	2·12
2	7·58	0·37	8·32	0·84	7·28	0·70	8·38	1·18	8·03	1·11	7·63	0·72
3	7·60	0·40	9·22	1·33	7·46	1·39	9·32	5·02	6·93	1·16	6·94	0·53
4	6·73	1·58	9·57	1·72	7·07	2·07	10·00	4·41	7·28	1·77	7·13	1·14
5	7·04	1·42	8·90	2·74*	6·85	1·71	8·99	3·26	7·93	1·16	7·57	0·33
6	6·43	0·56	7·24	1·63*	6·77	1·06	7·60	2·93	7·34	1·22	6·61	0·80
Whole life	6·68	0·95	8·28	1·48	6·64	1·20	8·61	2·69	7·49	1·10	7·07	0·73†
7H minus		0·64		0·94		0·63		1·00		0·83		0·34
8H plus		1·72		1·66		2·58		3·07		1·36		1·37

* In the last two quarters more successful pollens were in use.

† Based on bunches pollinated up to the end of 1958, when the planting was nearing the end of its useful life.

The first point to be made is that in the more fertile Fields V and VIII mean bunch size increased steadily for about the first year of bearing, reaching peaks respectively in the late and middle months of a year, which, as we saw for Field IV, are generally peak periods for bunch size. At the other extreme, in Fields IX and X, bunches in the initial bearing period (' plant crop ') were on the average appreciably larger than those of the succeeding crop.

The second and more important point is that, with the exception of Field X, and to a lesser extent Field IX, the plant crop is conspicuously inferior in seed yield to the succeeding ' ratoons ', even when the latter had a smaller average bunch. The exceptional Field X might well be explained by the unusually large plant crop bunches and the subsequent very sharp decline (accompanied by the very rapid spread of Panama disease in the more fertile parts of the field). This deficiency of seeds in plant bunches was previously noticed (SHEPHERD, 1954) for the first plantings at Bodles, flowering in the latter half of 1949. It was then ascribed, probably wrongly as it is now seen, to operational inefficiency. As said above, the Holland planting showed the same juvenile effect in 1948.

The discrepancies between the performances of the different fields are readily apparent from the same table. It is clear that the regression of seed yields on bunch sizes makes a sizeable contribution to these discrepancies, but the greater complexity of the situation is shown by the crude partition at the foot of the table into bunches with seven hands or less and those with eight hands or more. Field VIII was the best at all levels of bunch size and Field VII, it can be noted, yielded quite disproportionately in its larger bunches.

A more detailed look at the records for each field shows that the performance for a given bunch size has the same apparently fortuitous fluctuations as have been described for Field IV. Furthermore, the surges in this basic seed fertility do not necessarily coincide in time. Perhaps they are

rather a manifestation of some physiological rhythm in the plant, of which the plant crop effect is a part. Certainly it is hard to discern any external stimulus.

Not surprisingly, the same sort of heterogeneity may be evident within fields where the records permit a sub-division, as for instance in Field VIII at its peak period. The section arbitrarily identified as VIII B was superior in bunch sizes and seed yields to VIII A, even allowing for the fact that a better pollen, T23, was in use in the former. *Table 3* is included here as an indication of the level of seed fertility that can be realized and as a further illustration of the importance of bunch size.

Table 3. Field VIII B. Yields of bunches pollinated from May to July 1955, an example of extreme productivity

*Hands**	*Frequencies of bunches with seeds:*				*Total bunches*	*Total seeds*	*Mean seeds*
	0	1–5	6–10	11 *plus*			
6–8	4	8	0	0	12	18	1·50
9	5	29	16	4	54	300	5·56
10	13	51	22	24	110	754	6·65
11	9	26	15	15	65	532	8·18
12–13	3	4	5	8	20	228	11·40
Totals	34	118	58	51	261	1 832	7·02

* Mean bunch size for the whole sample was 10·09 hands.

POLLEN COMPARISONS

In the early days of Bodles, and at the earlier substations, the pollen in use was that of ' Pisang lilin ' (' Pisang lilan ' of earlier publications), an edible diploid of *Musa acuminata* having close affinities with the subspecies *malaccensis* of that species. From 1951 it was replaced by ' Long Tavoy ', a strain of *M. acuminata* subsp. *burmannica*, and by T14, the first of a now long series of selections from crosses involving wild and cultivated diploid forms of *M. acuminata*. The conviction rapidly grew that the seed yields from these pollens were unequal, although there are very few instances in the records where a critical and proper comparison can be made. Such comparisons were never consciously sought. The use of a pollen parent was determined by its other qualities and lowered yields were perforce accepted as an unavoidable disadvantage.

The objection to the bulk of the data is that the choice of a pollen to apply to any particular bunch was rarely even approximately random. A new pollen source, when plentiful enough, was usually applied exclusively to one field or even to one section of a field. The useful records then are those of transitional periods in one specified field when one pollen was gradually superseding another. An exception lies in the practice of 1952 and 1953 when new pollens were applied to the first two or three hands of each bunch and the remaining hands were pollinated with a parent of lower priority. Since the relative fertility of the successive hands of a ' Gros Michel ' bunch is known (SHEPHERD, 1954) a more direct measure is afforded, though ideally the pollens should be applied in random order

to the two portions of the bunch. This sort of comparison has the further advantages that infertile bunches, often a fair proportion, are not relevant and can be dismissed from consideration, and that data from more than one field can be combined.

It is possible by this method to compare T14 and T16, the first two 'synthetic' male parents to be extensively used. The data comprise 550 fertile bunches in five different fields (but mostly Field V), pollinated in 1953 and early 1954. In 355 of these T14 was applied to the basal hands, in 195, at the end of that period, T16 went on the basal hands. In all, the hands pollinated by T14 are estimated as equivalent to 285 whole bunches and these yielded 770 seeds, an average of 2·70 seeds per bunch. With T16 the equivalent of 265 bunches yielded 973 seeds, or 3·67 seeds per bunch. Thus T16 was about one and a third times as effective as T14, although both selections have the same, admittedly complex, parentage.

Other examples, listed in *Table 4*, depend on whole bunches pollinated concurrently in the same field. In some instances one pollen was evidently applied to somewhat larger bunches, on the average, and not at random,

Table 4. Comparisons of pollens based on concurrent use in same area

Comparison	*Field*	*First pollen*				*Second pollen*			
		Bunches	*Seeds*	$\bar{S}$	$\bar{H}$	*Bunches*	*Seeds*	$\bar{S}$	$\bar{H}$
T16 v T23	*IV*	217	397	1·83	7·04	55	163	2·96	7·35
	VIII A	373	486	1·33	8·16	42	85	2·02	8·14
	VIII B	490	831	1·70	8·34	80	217	2·71	8·27
	VIII B	40	273	6·82	10·57	39	372	9·54	10·59
T16 v T24	*VIII A*	323	561	1·74	8·77	89	302	3·39	9·03
	VIII B	49	126	2·57	8·88	40	175	4·37	9·10
T23 v T24	*VII*	31	9			31	11		
T23 v T25	*IX*	92	83	0·90	6·60	95	102	1·07	7·14
T25 v T28	*X*	76	33	0·43	7·15	30	17	0·57	7·33
	X	39	31	0·79	6·67	35	36	1·03	7·20
T27 v T28	*XI*	131	43	0·33	7·54	127	88	0·69	7·57

for which fact allowance must be made in drawing conclusions. On these data T23, T24, T25 and T28 are all roughly equal in performance, and are about one and a half times as effective as T16, about twice as effective as T27 (and T14, presumably).

It should be noted that pollen differences of similar magnitude have been found in pollinating other edible clones, some of them many times more fertile than 'Gros Michel' (SHEPHERD, 1959).

MANURIAL AND PRUNING EXPERIMENTS

From the account given above we can now see that there are two possible objectives in experiments varying the management procedure of the 'Gros Michel' breeding fields. The first is to increase seed yields by inducing larger bunches. The second is to find an empirical method of increasing yields regardless of bunch size.

In 1950 there were strong indications that the abandonment of the commercial practice of heavy pruning would be a method of this latter

kind (SHEPHERD, 1954), whereas it was at least conceivable to increase bunch size by more generous application of fertilizers. Accordingly, a combined trial was laid out in Field III in early 1951. Light pruning, with up to three 'trees' per stool, was compared with no pruning, and with each pruning treatment there were four manurial treatments, respectively, nil, nitrogen only, phosphate and potash, and all three nutrients. Fertilizer applications were made at six-weekly intervals and the amounts per plant were 3 oz. sulphate of ammonia, 1 oz. of superphosphate and $1\frac{1}{2}$ oz. of potash. Each of the eight treatments was applied to eight single plants at random in each of four blocks, a total of 32 plants per treatment. Wind damage delayed bearing until December 1951 and was largely responsible also for the small size of the bunches produced. Recording continued up to those bunches pollinated in September 1953, by which time Panama disease had greatly reduced the plant population.

Table 5. Manurial–pruning experiment in Field III 1952–53

Treatment	*Total bunches*	*Bunches reaped**	*Seeds*	$\bar{S}$	$\bar{H}$	*Panama disease*
No manure	136	110	60	0·55	5·52	37
N	142	107	61	0·57	5·39	45
PK	165	139	88	0·63	5·43	32
NPK	136	115	66	0·57	5·57	42
No pruning	281	215	57	0·27	4·80	82
Pruned to 3 trees	298	256	218	0·85	6·13	74
Block I	83	61	15	0·25	5·27	45
Block II	113	76	32	0·42	5·30	44
Block III	152	130	36	0·28	5·28	39
Block IV	231	204	192	0·94	5·67	28

* Many bunches were lost through winds and Panama disease.

The results are summarized in *Table 5* and the conclusions drawn are that:

(*a*) at the levels used, the fertilizers had no effect either on bunch size or on seed yield

(*b*) the application of nitrogen, with or without phosphate and potash, significantly increased the rate of spread of Panama disease (see RISHBETH, 1957; RISHBETH and NAYLOR, 1957)

(*c*) contrary to previous experience, plants lightly pruned to three trees yielded not only larger bunches but many more seeds than those unpruned

(*d*) the marked superiority of Block IV further illustrates the spatial heterogeneity discussed above.

At about the same time a pathology investigation was in progress in Field IV, in which two levels of sulphate of potash and one level of muriate of potash were being applied, together with an untreated control, to a 4×4 Latin Square layout with plots of 30 plants. The plants began to flower in February 1952 and bunches emerging up to October 1953 have

been included in *Table 6*. The error variance between plots was considerable (plot yields ranged from 16 to 113 seeds) and the differences cannot be regarded as significant. However, incomplete data from bunches emerging in the same plots in 1954 rank the treatments in the same order for mean hands and for mean seeds. It may be that heavy applications of potash actually depress yields.

Table 6. Potash fertilizer experiment in Field IV 1952–53

Fertilizer per year	*Bunches reaped*	*Seeds*	$\bar{S}$	$\bar{H}$*
6 lb K_2SO_4 *in 6 doses*	345	209	0·61	6·47
3 lb K_2SO_4 *in 12 doses*	373	311	0·83	6·86
3 lb KCl *in 12 doses*	389	276	0·71	7·00
No potash	377	302	0·80	6·67

* Based on bunches pollinated in 1953 only, about 60 per cent of the total.

One further manurial experiment has been attempted. 60 plants at random, from a block of 120, each twice received applications of 60 lb of pen manure at an interval of one year. The objective was to increase bunch size but even some months after the second application, this had not been achieved. Treated plants produced fewer bunches than untreated ones (74 against 96) in the recorded period and mean hands and mean seeds were approximately the same.

Now the apparent contradiction of the results on pruning above seemed to imply that the magnitude and even the direction of the pruning effect might well depend on the fertility of the field and its level of bunch sizes. A further experiment was set up in April 1954 comprising 100 ' triplets ' of plants in Field IV. Plants in each group of three were either pruned to three bearing trees, or pruned to two bearing trees, or unpruned. However, examination of the experiment some nine months later showed that there was little difference between the treatments in appearance or numbers of large shoots (trees and followers), as the mean bunch sizes of this first phase confirm (*Table 7*). Accordingly, the unpruned treatment was discarded and heavy pruning, to one tree and a follower, was substituted for these plants. It was not clear until some six months later that the treatments were taking effect and the records for this second phase (see *Table 7*) run from September 1955 to February 1957.

It is readily concluded that both mean hands and mean seeds per bunch increased with the intensity of pruning, although the total seed yield of the

Table 7. Pruning experiments in Field IV 1954–57

Pruning	*Bunches*	*Reaped*	*Seeds*	$\bar{S}$	$\bar{H}$
Phase 1					
2 trees	110	106	157	1·48	6·82
3 trees	104	98	103	1·05	6·71
No pruning	122	110	195	1·68	6·74
Phase 2					
1 tree	100	95	167	1·76	7·17
2 trees	165	153	168	1·10	6·54
3 trees	164	142	105	0·74	6·13

heavily pruned plants was not greater than that of the moderately pruned ones. In the 1950 experiment, with mean bunches in excess of nine hands, bunch size had evidently ceased to be a limiting factor and seeds per bunch decreased with heavier pruning. There is the interesting theoretical possibility that at some intermediate level pruning will increase bunch size without any effect on mean seed yield. Practically, pruning must obviously be related to the age and fertility of the field.

TIME OF DAY OF POLLINATION

It was previously reported (SHEPHERD, 1954) that pollination of ' Gros Michel ' in the early morning, rather than later in the day, enhanced yields. Subsequent experiments of the same type are recorded in *Table 8*. Bunches were assigned at random to each of three pollinating times ranging from early morning to the middle of the day. Three trials were performed as it was thought that results might vary at different times of the year. The first was in a cool, dry period, the second in a hot dry period, the last during the season of peak rainfall at the Bodles station. The results were not, in fact, consistent between trials. However, it is evident that pollination in the middle of the day is never advantageous and that mid-morning is generally the best time, despite the previous evidence.

Table 8. Time of day of pollination

Duration of trial	*6 a.m.*		*10 a.m.*		*1 p.m.*	
	Bunches	$\bar{S}$	*Bunches*	$\bar{S}$	*Bunches*	$\bar{S}$
29.1.55 to 19.2.55	32	1·44	31	1·45	42	0·71
1.7.55 to 22.7.55	41	3·02	42	3·50	42	3·12
14.9.55 to 11.10.55	47	1·36	47	1·62	45	1·31

The reason for these differences was revealed by experiments on other edible clones (SHEPHERD, 1959), when it was found in some cases that seed yields were increased by the pollination of unopened flowers on the day preceding receptivity. Success was in some way related to the age of the flowers. A similar experiment, comparing normal morning pollination with pre-receptive afternoon pollination in ' Gros Michel ', confirmed the finding above in that premature pollination depressed seed yields.

NOTES ON GERMINATION

While strictly outside the scope of this report, germination problems are obviously complementary to those of seed production, and a few general observations will round off the picture.

Germination of ' Gros Michel ' seeds, in common with those of other edible clones, is notably poor and slow. Seedlings may appear up to six months or more from sowing and the total is only of the order of one quarter to two fifths of the seeds sown. Many of the seedlings are either useless dwarf heptaploids or weaklings (probably mostly aneuploid) and the yield of useful tetraploid seedlings is of the order of 5 to 10 per cent. Tetraploids and heptaploids germinate at about the same rate. SIMMONDS (1952 and 1959a) has largely elucidated the optimal conditions for germination and

there seems to be little hope for any substantial improvement in seedling yields, although they are still rather variable from time to time. It is some reassurance to find that germination and the frequency of tetraploids are apparently unaffected by the level of fertility of the bunches from which the seeds came (SHEPHERD, unpublished). There is some evidence that crosses with different pollens may have different viabilities and different relative numbers of useful and useless seedlings. Further study on these lines should be interesting but is unlikely to lead to any practical gain.

CONCLUSIONS

In all it must be said that the work reported has only led to a better understanding of the problems, rather than to any practical solution. It is true that something can be achieved by the choice of more fertile land and by the careful manipulation of pruning practice, but there is no satisfactory explanation of the cause or causes of a major part of the variability encountered, the fortuitous fluctuation in time described above. However, the possibilities for practical investigation are not exhausted. Among them, experiments in crop timing are currently contemplated, efforts to concentrate the plant crop and, especially, the first ratoon crop in seasons favourable to greater bunch size. The interactions of such timing with pruning practice need to be known also. The optimal practice may employ different intensities of pruning for different seasons.

Further, observations and experiments of the type described above are but one approach to the problems. The other is through a continuation of the studies of the biochemistry and physiology of fruit development initiated by SIMMONDS (1953 and 1959b). There are grounds for thinking that much sterility in ' Gros Michel ' is directly caused by competitive parthenocarpic development and, though there has yet been little promise of success, it may be possible by chemical means to alter the physiological balance of the ovary and young fruit to favour fertilization and seed development. This is essentially a more direct approach than that of the work presented above, in which it is sought to modify the physiological balance of the whole plant to achieve an indirect effect on a part.

SUMMARY

Further data are presented on the variation in seed yields of ' Gros Michel ' pollinated at different times and at different sites. Fluctuation in time is partitioned into two fractions, one seasonal, the other uncertain but in part connected with the age of the field. General soil fertility, as measured by the average size of the fruit bunch, is shown to be important, but experiments show no practical advantage from the fertilizer applications tried. Yields are also shown to be influenced appreciably by the pruning practice adopted, by the age of the flowers when pollinated and by the source of the pollen, despite the close affinity of the pollen parents used.

ACKNOWLEDGEMENTS

The author is indebted to G. E. Hodnett for his advice on the handling of the serial data from Field IV.

(*Received September 1959*)

REFERENCES

QUENOUILLE, M. H. (1952). *Associated Measurements.* Butterworths: London

RISHBETH, J. (1957). 'Fusarium wilt of bananas in Jamaica, II—Some aspects of host-parasite relationships'. *Ann. Bot., Lond. N.S.* **21,** 215–245

RISHBETH, J. and NAYLOR, A. G. (1957). 'Fusarium wilt of bananas in Jamaica, III—Attempted control'. *Ann. Bot., Lond., N.S.* **21,** 599–609

SHEPHERD, K. (1954). 'Seed fertility of the Gros Michel banana in Jamaica'. *J. hort. Sci.* **29,** 1–11

SHEPHERD, K. (1959). 'Seed fertility of edible bananas'. *J. hort. Sci.* In press

SIMMONDS, N. W. (1952). 'The germination of banana seeds'. *Trop. Agriculture, Trin.* **29,** 2–16

SIMMONDS, N. W. (1953). 'The development of the banana fruit'. *J. exp. Bot.* **4,** 87–105

SIMMONDS, N. W. (1959a). 'Experiments on the germination of banana seeds'. *Trop. Agriculture, Trin.* **36,** 259–273

SIMMONDS, N. W. (1959b). 'Experiments on banana fruit development'. *Ann. Bot., Lond., N.S.* In press

A Comparison of Urea with Ammonium Sulphate as a Nitrogen Source for Sugar-cane

D. H. Parish and S. M. Feillafé

Sugar Industry Research Institute, Réduit, Mauritius

The standard nitrogenous fertilizer used in Mauritius and indeed in most of the tropical world is ammonium sulphate, as per unit of nitrogen it has been cheaper than, and as efficient as, any other form of nitrogen available.

In the last few years commercial urea has appeared on the market in substantial amounts. This material has proved tempting for the cane planter in that the price per unit of nitrogen is slightly lower than that paid for ammonium sulphate. In addition because of its high nitrogen content, 46 per cent as against 21 per cent for sulphate of ammonia, transport costs are low.

Many estates have used urea on a small scale, but some misgivings were felt as it was known that the urea contained biuret, a material which has proved detrimental to the yield of certain plants, notably the pineapple (Stanford, 1954).

In 1956 and 1957 therefore field experiments were laid down to test urea against ammonium sulphate as a nitrogen source for sugar-cane.

EXPERIMENTAL

A randomized block lay-out was used with the two forms of nitrogen at four levels each, viz. 0, 15, 30 and 45 kg of nitrogen per acre; the fertilizer being applied on the stool as is the usual practice in Mauritius.

Ten sites were chosen to cover the range of climatic and soil conditions met with locally. The final results were obtained from 4 virgin and 17 ratoon harvests.

Third leaf punches were taken as recommended by Halais (1955) for foliar diagnosis.

The experimental sites were checked for phosphorus and potash status and found to be satisfactory.

RESULTS

Figure 1 gives two pairs of curves, the upper pair being the effect of the increasing levels of nitrogen application on the yields of cane in tons/acre, and the lower pair the foliar levels of nitrogen at the various levels of fertilization expressed as a percentage of the control.

The graphs show that the ammonium sulphate curve is superior in each

case to the urea curve. The difference between the mean of yields of cane per acre at the 45 kg level is highly significant ($P=0{\cdot}01$).

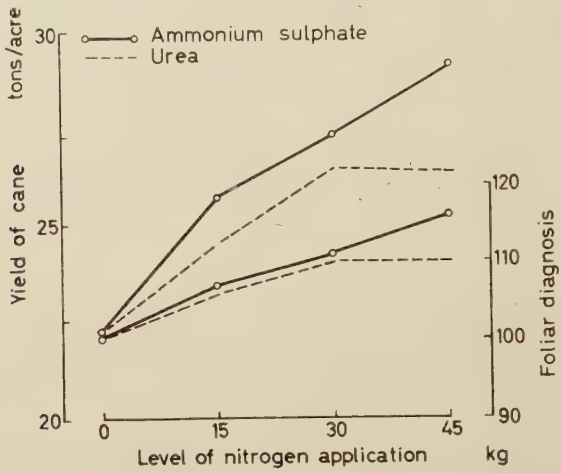

Figure 1. Influence of increasing levels of nitrogen fertilization on yield of cane in tons/acre (above) and the foliar levels of nitrogen expressed as a percentage of the control (below)

DISCUSSION

The results show clearly that for sugar-cane in Mauritius urea is not as effective a source of nitrogen as is ammonium sulphate.

This finding is contrary to findings in Australia (VALLANCE, 1957) but is supported by the few Jamaican results so far published (S.M.A.J., 1957).

There are several scientific reasons which could be held to account for the comparatively poor performance of urea, namely:

(*a*) Apart from the nitrogen, ammonium sulphate provides another essential element

(*b*) Biuret toxicity (STANFORD, 1954)

(*c*) Conversion of urea to ammonium cyanate and consequent toxic effects (ROTINI, 1956)

(*d*) Leaching losses due to slow conversion of the urea to ammonium carbonate (BROADBENT, HILL and TYLER, 1958)

(*e*) Higher nitrification rate than sulphate of ammonia and subsequent leaching of nitrate (SOUBIES, GADET and LENAIN, 1955)

(*f*) Losses of ammonia due to volatilization (SOUBIES, GADET and LENAIN, 1955)

Field experiments in Mauritius have shown that sulphate is not limiting cane growth, and a preliminary pot experiment has shown that biuret is toxic to cane only at doses far beyond those which would be applied with urea in practice.

Which of the remaining factors, if any, is operative with sugar-cane is not known, but in view of the fact that cane soils have high temperatures and a very active microflora the last two possibilities seem the more probable.

Studies on all the possible causes are in progress, and until such time as the reasons for the poor utilization of urea nitrogen become available, planters in Mauritius are being advised not to change from ammonium sulphate.

When more is known about urea, then modifications of the current methods of fertilizer application such as applying the urea under the trash, covering it with soil, and using split applications may improve its value to the point where it could be used economically.

NOTE ADDED IN PROOF

Since this article was submitted VOLK (1959) has shown that surface applied urea may lose considerable quantities of nitrogen by ammonia volatilization following the decomposition of the urea by urease.

We have repeated Volk's experiments and the results obtained show that very heavy losses of urea nitrogen do occur following surface application.

In view of the intense biological activity occurring in tropical soils it would seem reasonable to think of urea merely as a convenient way of storing and applying the unstable salt ammonium carbonate.

With this concept, measures to prevent volatilization losses of ammonia will then be taken automatically.

SUMMARY

Field experiments carried out in Mauritius have shown that urea is not as efficient as ammonium sulphate in supplying nitrogen to sugar-cane. Possible reasons for this poor performance of urea are suggested.

(*Received October 1959*)

REFERENCES

BROADBENT, F. E., HILL, G. N. and TYLER, K. B. (1958). 'Movement of urea in soils'. *Calif. Agric.* December 1958, p 9

HALAIS, P. (1955). 'Foliar diagnosis'. *Rep. Mauritius Sugar Ind. Res. Inst.*, p 41

ROTINI, O. T. (1956). 'Urea biureto e acido cianico nella fertilazzione azotata delli colture agrarie'. *Pubbl. Univ. Pisa.* Abstracted in *Soil Sci.* 1956, **82,** 349

SOUBIES, L., GADET, R. and LENAIN, M. (1955). 'Recherches sur l'évolution de l'urée dans les sols et sur son utilisation comme engrais azoté'. *Ann. Inst. nat. Rech. agron., Paris, Sér. A,* pp 997–1033

STANFORD, W. G. (1954). 'Toxicity to pineapple plants of biuret formed in urea fertilizers from different sources'. *Science,* **120,** 349–50

Sugar Manufacturers' Association of Jamaica. (1957). *Annual Report* of the Research Department, p 18

VALLANCE, L. G. (1957). *57th Ann. Rep. Bur. Sug. Exp. Stas. Qd,* p 21

VOLK, G. M. (1959). *Agron. J.* **51,** 746–749

The Effect of Soil Type and Soil Moisture Content on Growth of Sugar-cane in the East Coast Area of Demerara

B. Walker*

Bookers' Sugar Estates, Ltd, British Guiana

Four main types of soil are found in the flat, low-lying sugar-cane belt of the east coast of Demerara. This area, which accounts for approximately one quarter of the total sugar production of British Guiana, stretches from the eastern boundaries of Georgetown along the sea coast to the east for about fifteen miles. The low coastal plain extends inland for a depth varying between ten and fifteen miles, but sugar-cane is not grown more than half this distance inland, the area extending behind the cane plantations being the main fresh water conservancy for the east coast estates and Georgetown itself. Small rice farms and common pastures occupy the mile or more between the sugar estates and the sea wall. This land is extremely saline and very unproductive.

SOIL TYPES

The four distinct soil types in the cane growing area are saline clays, heavy blue clays, sands and pegasse.

(*1*) Saline sodium/magnesium clays are found in areas adjoining the sea coast. The most saline of these soils are not used for cane cultivation, and of the total area devoted to cane, only about 10 per cent can be classed as saline sodium/magnesium clay.

(*2*) Frontland clay accounts for approximately 75 per cent of the area of the cane belt. If treated correctly this soil can give extremely high yields of cane per acre, but it has often a high content of iron, aluminium and manganese which makes the control of the pH and water table most important. Frontland clay is generally found immediately inland from the saline clays.

(*3*) Sands, like the other types of soil in this area, occur in belts running roughly parallel with the sea coast. Thus although there are rarely any belts of sand running through the saline clay soils, there are often three or four major sand reefs extending in an east–west direction through the wider belt of frontland clay. These reefs are usually several feet higher than the surrounding areas and from a few yards to half a mile in width. They make up 5 to 10 per cent of the cane growing area.

* Now Cane Farming Officer, British Honduras.

(*4*) Pegasse, the fourth soil type, is only found to any extent at the most inland edge of the sugar-cane belt. In fact this type of soil has largely determined the inland boundary of cane plantations, for although only 5 to 10 per cent of the cane growing area of the coastal plain is pegasse, practically the whole of the inland fresh water conservancy area is made up of this type of soil. It is a brownish black soil with a very high organic matter content and often a high sulphide reaction and extremely low calcium index.

Chemical analysis of a 1:5 soil/water extract was made using the methods suggested by EVANS (1955). *Table 1* shows the chemical characteristics of each soil type.

Table 1. Chemical analysis of soil/water extract from four different areas

Depth in.	pH	SO_4 *p.p.m.*	Cl *p.p.m.*	Ca *p.p.m.*	Mg *p.p.m.*	Fe *p.p.m.*	K *p.p.m.*	Na *p.p.m.*	
0–12	4 7	25	102	25	200	5	15	140	*Saline clay*
12–24	6 1	25	136	20	250	30	30	210	
24–36	6 2	62 5	374	40	200	5	44	425	
0–12	5·2	72 5	204	40	45	30	9	90	*Frontland clay*
12–24	5·2	25	408	50	25	20	9	85	
24–36	4 6	200	136	50	200	20	9	105	
0–12	4 2	25	238	25	200	50	9	90	*Sand*
12–24	4 7	37 5	204	5	150	50	6	90	
24–36	4 6	25	238	40	250	5	10	130	
0–12	4 6	25	544	15	70 2	200	12	70	*Pegasse*
12–24	3 7	75	680	5	10	80	8	60	
24–36	4 7	50	952	5	10	200	8	60	

WEEKLY GROWTH MEASUREMENTS

Two fields of cane were selected on each type of soil, the cane being in the ' boom period of vegetative growth ' (3 to 8 months), and measurements of elongation were made weekly. The measurement taken was from ground level to the top visible dewlap (TVD). Three canes were measured at each of two different places within the field, i.e. a total of six canes per field. Variety growth rate differences were found to be negligible. *Tables 2* to *5* show the rate of growth on the four soil types.

Table 2. Growth of cane on saline clay soil

Date: week ending	*Rainfall in week, in.*	*3rd ratoon Age, weeks*	*B37161 Growth, cm/wk*	*1st ratoon Age, weeks*	*B41227 Growth, cm/wk*
8.8.58	0·65	14	3·1	16	4·3
15.8.58	2·05	15	11·7	17	17·5
22.8.58	0·12	16	9·5	18	15·1
29.8.58	0·59	17	8·7	19	11·9
5.9.58	0·00	18	5·3	20	12·7
12.9.58	1·48	19	6·2	21	13·7
19.9.58	0·10	20	8·7	22	10·3
26.9.58	0·00	21	4·5	23	4·6
3.10.58	0·00	22	2·4	24	1·4
10.10.58	0·01	23	1·9	25	0·5
17.10.58	0·06	24	1·2	26	1·6
24.10.58	0·02	25	0·8	27	0·8
31.10.58	0·97	26	3·5	28	1·0
7.11.58	0·00	27	2·1	29	1·3
22.11.58	0·00	29	1·7	31	1·3
29.11.58	0·00	30	2·4	32	1·2
5.12.58	0·03	31	3·0	33	0·6
12.12.58	0·88	32	3·6	34	1·3
19.12.58	0·67	33	1·6	35	1·2
9.1.59	0·50	36	5·2	38	1·3

Table 3. Growth of cane on frontland clay soil

Date: week ending	*Rainfall in week, in.*	*Plant cane Age, weeks*	*B41227 Growth, cm/wk*	*2nd ratoon Age, weeks*	*B37161 Growth, cm/wk*
8.8.58	0·51	20	14·4	13	5·2
15.8.58	2·57	21	20·2	14	6·1
22.8.58	0·15	22	10·9	15	8·7
29.8.58	0·40	23	16·0	16	9·1
5.9.58	0·04	24	9·3	17	4·4
12.9.58	1·28	25	6·7	18	6·9
19.9.58	0·05	26	8·1	19	5·8
26.9.58	0·00	27	1·9	20	3·9
3.10.58	0·00	28	5·2*	21	2·9
10.10.58	0·03	29	13·5	22	1·8
17.10.58	0·09	30	11·1	23	1·3
24.10.58	0·33	31	3·7	24	1·5
31.10.58	1·29	32	2·1	25	1·7
7.11.58	0·09	33	2·0	26	2·1
22.11.58	0·00	35	3·7†	28	1·4
29.11.58	0·00	36	7·2	29	1·8
5.12.58	0·16	37	8·6	30	3·3
12.12.58	1·60	38	9·7	31	4·3
19.12.58	0·80	39	5·3	32	2·2
9.1.59	0·76	42	2·7	35	5·4

* Irrigated by flooding 1.10.58. † Irrigated by flooding 20.11.58.

Table 4. Growth of cane on sandy soil

Date: week ending	*Rainfall in week, in.*	*2nd ratoon Age, weeks*	*B37161 Growth, cm/wk*	*2nd ratoon Age, weeks*	*B37161 Growth, cm/wk*
8.8.58	0·65	15	9·5	19	6·9
15.8.58	2·40	16	11·4	20	9·4
22.8.58	0·16	17	14·0	21	9·8
29.8.58	0·57	18	10·7	22	8·5
5.9.58	0·04	19	6·8	23	5·9
12.9.58	1·76	20	6·5	24	4·5
19.9.58	0·07	21	4·9	25	4·9
26.9.58	0·00	22	3·1	26	5·8
3.10.58	0·00	23	2·1	27	3·1
10.10.58	0·02	24	2·6	28	5·1*
17.10.58	0·00	25	1·6	29	6·7
24.10.58	0·32	26	1·2	30	2·4
31.10.58	1·52	27	1·9	31	2·0
7.11.58	0·13	28	3·3	32	2·7
22.11.58	0·00	30	1·9	34	2·7
29.11.58	0·00	31	2·2	35	4·2
5.12.58	0·29	32	3·2	36	1·8
12.12.58	1·78	33	3·3	37	2·2
19.12.58	0·57	34	4·8	38	4·6
9.1.59	0·26	37	3·0	41	3·3

* Irrigated by flooding 7.10.58.

Table 5. Growth of cane on pegasse soil

Date: week ending	*Rainfall in week, in.*	*Plant cane Age, weeks*	*B47258 Growth, cm/wk*	*1st ratoon Age, weeks*	*B37161 Growth, cmk/w*
8.8.58	0·46	13	2·9		
15.8.58	3·20	14	2·4		
22.8.58	0·19	15	3·3		
29.8.58	0·34	16	4·8		
5.9.58	0·08	17	5·7	5	8·0
12.9.58	1·43	18	7·1	6	7·5
19.9.58	0·00	19	7·7	7	7·2
26.9.58	0·00	20	5·3	8	5·5
3.10.58	0·00	21	9·5	9	7·4
10.10.58	0·05	22	9·1	10	6·1
17.10.58	0·00	23	6·2	11	7·0
24.10.58	0·65	24	6·7	12	7·0
31.10.58	1·62	25	7·2	13	6·5
7.11.58	0·18	26	7·8	14	9·5
22.11.58	0·00	28	7·3	16	9·7
29.11.58	0·00	29	6·4	17	8·6
5.12.58	0·16	30	6·2	18	8·1
12.12.58	1·63	31	7·5	19	7·4
19.12.58	0·76	32	5·9	20	5·3
9.1.59	0·58	35	3·3	23	4·6

From these and similar weekly measurements of growth it becomes apparent that the rate of growth is closely correlated to the supply of water which is available to the plant, and that irrigation requirements, as measured by the rate of growth of the cane, differ markedly depending on the type of soil. For example, cane growth on the pegasse soil is much less affected by lack of rainfall than that of cane grown on sandy soil under similar circumstances.

AVAILABLE WATER FOR PLANT GROWTH

The amount of water which the soil is capable of retaining for plant growth may be taken as the difference between the water available to the plant at field capacity (FC) and that available to the plant at permanent wilting point (PWP), and this will vary considerably with the type of soil considered.

Field capacity has been defined as the amount of water, expressed as a percentage of the oven-dry soil, held in a soil after the excess of gravitational water has drained away, and after the rate of downward movement of water has materially decreased (Viehmeyer and Hendrickson, 1931). This was determined in duplicate on each of the four soil types at different profile depths by the field method suggested by Piper (1950a).

Permanent wilting point is reached when the moisture content of the soil, expressed as a percentage of the dry weight, is such that the soil can no longer supply moisture to a plant growing in it at sufficient rate for the plant to maintain turgor and the plant thus wilts permanently. This point was determined experimentally by the method of Marshall and Williams adapted by Piper in Australia (1950b). *Table 6* shows the field capacity and *Table 7* the permanent wilting point coefficients of the four soil types at different profile depths.

Table 6. Field capacity coefficients at different depths in four types of soil

Depth in.	*Saline clay*	*Frontland clay*	*Sand*	*Pegasse*
0–12	41·8	40·8	20·5	51·5
12–24	44·4	46·5	19·4	50·9
24–36	45·0	55·0	23·1	73·9

Table 7. Permanent wilting point coefficients at different depths in four types of soil

Depth in.	*Saline clay*	*Frontland clay*	*Sand*	*Pegasse*
0–12	19·3	26·6	14·4	35·5
12–24	26·5	24·3	13·2	29·9
24–36	28·8	24·0	12·6	*Complete growth failure*

As both measurements of field capacity and permanent wilting point coefficients are related to dry soil, it is necessary to determine the weight/volume of the different soils under the conditions obtaining in the actual fields. A soil profile pit was therefore dug in each soil type area and 6 in. cubes of soil carefully taken from the middle of each vertical depth division. The soils had previously been brought up to field capacity *in situ*. Knowing the field capacity and permanent wilting point coefficients for each soil type depth horizon, it was only necessary to weigh the cubes of soil to determine the amount of water in the soil at these two points, and thus the laborious drying of a large volume of soil was avoided. The percentage of water (x) in soil at FC is given by the equation

$$x = 100\ \mathrm{FC}/(100+\mathrm{FC})$$

The weight of water (y) in 1 cubic foot of soil at FC is therefore

$$y = (1/100)x \times \mathrm{Wt\ of\ 1\ ft^3\ of\ soil\ at\ FC}$$

Similar calculations will give the weight of water in a volume of soil at PWP. Having found the weight (and thus volume) of water available for plant growth at FC and PWP, these data can be translated to the equivalent inches of water (or rainfall) available to the plant for growth between these two soil moisture points. *Table 8* shows the inches of water available to the plant when the four different soil types are at FC and PWP.

It is of interest to note in *Table 8*, that of the four soils selected, sand has the lowest capacity to supply water for plant growth, assuming in each case that the cane roots only penetrate to a depth of 3 ft. For example, taking the clay soil and the sandy soil selected for this work, a moisture deficit of 2 in. in each case means that the cane growing on the sandy soil is under a much more severe water stress than cane growing on frontland clay soil, as the former is only capable of supplying approximately 4½ in. per 3 ft depth, while the latter has a 'reservoir' of water available for plant growth of over 9 in. This is in agreement with the findings when weekly growth measurements are taken and compared with available water,

Table 8. Inches of water per cubic foot of soil at field capacity (a), *permanent wilting point* (b), *for plant growth between these points* (c), *and density of soil* (d)

Depth in.	*Saline clay*				*Frontland clay*			
	d	*a*	*b*	*c*	*d*	*a*	*b*	*c*
0–12	1·65	5·62	2·68	2·94	1·76	6·08	3·96	2·12
12–24	1·61	5·98	3·54	2·44	1·63	6·23	3·23	3·00
24–36	1·70	6·31	4·04	2·27	1·72	7·29	3·18	4·11
Total				7·65				9·23

Depth in.	*Sand*				*Pegasse*			
	d	*a*	*b*	*c*	*d*	*a*	*b*	*c*
0–12	1·86	3·77	2·65	1·12	1·37	5·57	3·84	1·73
12–24	1·80	3·48	2·38	1·10	1·62	6·56	3·74	2·82
24–36	2·04	4·64	2·50	2·14	1·54	7·80	—	+
Total				4·36				4·55 +

It is felt that where cane is irrigated at certain fixed levels of moisture deficit, the moisture-supplying capacity of the particular type of soil, and the depth to which the moisture-absorbing roots of the plant have penetrated must be previously determined before this method of irrigation control can be fully utilized with confidence.

DETERMINATION OF WATER LOSS BY CANE TRANSPIRATION

The soil which supports a growing crop covering the ground completely loses water almost wholly by transpiration of the crop. The amount of this water loss has been shown to depend primarily on meteorological conditions rather than on the kind of crop. It has been calculated from such meteorological data by a formula employed by PENMAN (1948). The relationship between the water lost to the atmosphere from a standard area of growing vegetation (E_t) and the water lost to the atmosphere from an equal area of open water (E_o) has been investigated by several authors. Thus MUSGRAVE (1950) found the ratio $E_t/E_o = 0{\cdot}60$; PENMAN (1952) obtained a ratio of 0·61 with lucerne in Australia; and COWAN and INNES (1956) using sugar-cane in Jamaica obtained a value for E_t/E_o of 0·58. DAVIES (1959) working at Ogle on the east coast of Demerara established a ratio E_t/E_o of 0·66 over a period of 12 months.

CONTROL OF IRRIGATION

Using Davies's value of 0·66 and the measurement of daily water loss from a series of open-pan evaporimeters, the calculation of the daily water loss by an area of growing sugar-cane becomes a simple routine. Thus on Enmore Estate in the east coast district of Demerara, the author found that for a period of 70 weeks ending in November 1959, the daily open water evaporation (E_o) was 0·364 in. and the daily water loss by cane (E_t) was 0·24 in.

It is suggested that this method of investigation could be used to determine at what water deficit levels it is best to irrigate cane growing on each of the four main soil types which occur in the east coast district of Demerara.

SUMMARY

The influence of four different types of soil—saline clay, acidic frontland clay, sand and pegasse—on the rate of growth of sugar-cane in the east coast district of Demerara is discussed. The rate of growth is shown to be closely correlated with the availability of moisture in the soil for plant growth. The volume of this moisture was found to vary with the type of soil considered. Field capacity and permanent wilting point coefficients have been found for each soil type by experimentation, and measurements of the soil densities have been made. Using these data, calculations have been made to determine the volume of water available for plant growth on each soil type. The water loss by evapotranspiration of an area of growing vegetation has been investigated and a method of using data from open-pan evaporimeters in the calculation of the daily water loss from sugar-cane has been indicated. It is suggested that having found the total volume of water available for plant growth on each of the four soil types and calculating the rate of water loss from growing cane, these data could be used to determine the irrigation requirements of cane growing on different types of soil within a relatively small area.

(*Received December 1959*)

REFERENCES

COWAN, I.R. and INNES, R. F. (1956). *Proceedings* of the International Society of Sugar Cane Technologists 9th Congress

DAVIES, N. L. (1959). Private communication

EVANS, H. (1955). 'A practical method of approach to some soil problems affecting sugar-cane growth in British Guiana'. *Proc. B.W.I. Sugar-cane tech. Conf. 1955*

MUSGRAVE, G. D. (1950). *Estimating Evapotranspiration.* Mimeograph, U.S.D.A. Soil Conservation Service

PENMAN, H. L. (1948). *Proc. Roy. Soc. A*, **193,** 120–145

PENMAN, H. L. (1952). *Rep. 13th int. hort. Congr.* Vol. II, 913–924

PIPER, C. S. (1950). *Soil and Plant Analysis*, **4,** 91–92

PIPER, C. S. (1950). *Soil and Plant Analysis*, **4,** 95–96

VIEHMEYER, F. J. and HENDRICKSON, A. H. (1931). *Soil Sci.* **32,** 181–193

A Spraying and Harvesting Trial in Trinidad against Cocoa Pod Diseases

P. Holliday

Commonwealth Mycological Institute, Kew, England

In Trinidad two fungi, by infecting the pods, probably account for nearly all the direct cocoa bean losses from disease. They are *Marasmius perniciosus* Stahel (witches' broom) and *Phytophthora palmivora* Butler (black pod). Losses from *Botryodiplodia theobromae* Pat. (brown pod) and *Colletotrichum* sp. (anthracnose) are much less. The former fungus appears to be entirely secondary.

Witches' broom can be controlled in well-kept stands by removing the brooms twice yearly at specific times (Baker and Crowdy, 1943; Holliday, 1954a). But in the wetter areas (> 100 in. a year) this may not achieve satisfactory control of pod infection. Pod spraying, in addition to broom removal, has therefore been tried. Thorold (1953a) reduced pod infection with 20 applications of one per cent Bordeaux mixture at monthly intervals. Holliday (1954c) similarly reduced infection with six applications during the wet season. Perenox (cuprous oxide) was unsatisfactory. These trials were carried out in a lower rainfall area (< 100 in. a year). In a further trial in a wetter region perenox and blitox (copper oxychloride) gave a little control (Holliday, *loc. cit.*).

Dale (1953) considered that it might be possible to control both black pod and witches' broom pod infections simultaneously by spraying since both are serious at about the same time. Black pod control in Trinidad has, until recently, been largely ignored. This disease is generally less serious than witches' broom partly because it is more restricted by climatic factors, and partly because the more frequent harvestings in the West Indies—compared with West African practice—tend to reduce losses. Unlike *M. perniciosus*, invasion by *P. palmivora* is at first restricted to the pod shell, the beans being unaffected. Thus, if pods are picked promptly, more beans are recovered.

The main crop sets at the start of the wet season about June. Most of it is reaped between December and April. The heaviest witches' broom infection occurs between July and December during the wet season. But since the incubation period is some 3 months (Dale, 1946) infected pod counts are highest between October and March (Holliday, 1954a). The incubation period for black pod is a few days. Therefore rainfall more quickly results in its incidence. It is probably most severe towards the end of the wet season between October and December. Presumably inoculum build-up during the early part of the wet season must occur after the previous dry season from February to May. Only young pods are attacked by *M. perniciosus* whereas *P. palmivora* can infect those of any age.

METHODS

Site

This was a reasonably uniform, mature field in a commercial estate (Non Pareil) in East Trinidad. The estate is in a high rainfall area ($\pm$130 in. a year) where incidence of both diseases could be expected to be severe. The trees were mostly (94 per cent) Imperial College Selection (ICS) 1. Planting had been a little irregular, because of the system of deep drains used, but about the customary 12 $\times$ 12 ft. An L-shaped single area of 288 trees was selected. It was divided into 6 blocks each with 6 plots of 8 trees each and to which the treatments were assigned at random.

Treatments

There were:

Sprayed (*1*) 12 times—2-weekly intervals
Sprayed (*2*) 8 times—4-weekly intervals
Sprayed (*3*) 4 times—8-weekly intervals
Unsprayed (*4*) Harvested—once every week
Unsprayed (*5*) Harvested—once every 2 weeks
Unsprayed (*6*) Harvested—once every 4 weeks

The sprayed plots were harvested once every 4 weeks. Thus treatment (6) was a control. In estates it is customary to harvest once a month, so that the treatment for the control plots accorded with local estate routine. Blitox was the fungicide applied, at a copper equivalent of one per cent Bordeaux mixture. Cylindrical pattern, hand pumped, low pressure units with a working capacity of $2\frac{1}{2}$ gallons and with low volume T-jet nozzles were used. Ordinary estate labour was employed and only the cropping regions—pods of all ages—were sprayed. No attempt was made to apply a fixed quantity per tree. The amount was estimated at 10 to 30 gallons per acre according to the size and number of pods. Applications began in July 1954 and ended in January 1955.

Records

Counts of all pods over 10 cm in length were taken at each harvest and placed in one of the following five categories:

	Symbol (as in tables)
(*1*) Healthy, ripe	*H*
(*2*) Witches' broom infection	*WB*
(*3*) Black pod infection	*BP*
(*4*) Other disease (fungal)	*OD*
(*5*) Animal damage	*A*

In each category, besides the pod count, the wet weight of good beans was taken. The 10 cm length limit was imposed because up to this maximum size, approximately, ICS 1 pods are liable to cherelle wilt, a physiological condition. Pods infected below this size and which subsequently wilted were not recorded. Category *4* (*OD*) consisted largely of pods infected by *B. theobromae* but with no clear sign of animal damage. A few had probably been initially attacked by the primary pathogens but the rapidly developing brown pod infection made field determination uncertain. Recording began in August and ended in February. It had been intended to gather the whole season's crop but a misunderstanding with the estate staff made this not possible. Percentages have been transformed before analysis (FISHER and YATES, 1953).

RESULTS

Treatment effects on disease incidence

(See *Tables 1, 2, 3* and *4.*) All the spray treatments significantly reduced black pod, the incidence falling with increasing frequency of application. The weekly harvested plots were also significantly lower in black pod incidence. Witches' broom was significantly worse in the weekly harvested plots compared with all other treatments which, within themselves, show no differences (*Table 1*). In the 'other diseases' category both weekly and fortnightly harvesting intervals were significantly better than the control and fungicide treatments (*Table 2*).

Table 1. Percentage pod infection by witches' broom (WB) and black pod (BP) as means per plot

Treatments:	*Sprayed, no. applications* 4	8	12	*Harvest interval, weeks* 1	2	4	*Crit. diff.* 5%
WB Oct to Feb							
Total pods	208·8	167·0	196·0	206·7	210·5	195·7	
Infection	30·82*	31·40	31·63	40·38	33·28	31·92	4·12
	(27·1)	(27·0)	(29·8)	(41·9)	(29·8)	(28·2)	—
BP. Aug to Jan							
Total pods	181·2	152·2	181·2	223·0	221·7	192·7	
Infection	22·10	18·43	17·72	23·97	29·58	31·38	7·13
	(14·6)	(10·8)	(9·3)	(16·4)	(23·9)	(27·9)	—

* Without parentheses transformed; within parentheses actual percentages.

Table 2. Percentage pod infection by other diseases (OD) and destruction by animals (A) as means per plot (Harvest Aug to Feb)

Treatments:	*Sprayed, no. applications* 4	8	12	*Harvest interval, weeks* 1	2	4	*Crit. diff.* 5%
Total pods	235·7	191·8	222·2	254·4	245·3	224·2	48·07
OD-infection	15·57*	14·23	14·20	5·47	8·90	16·82	3·22
	(7·1)	(6·2)	(5·8)	(1·3)	(2·5)	(8·6)	—
A-destruction	12·98	12·67	13·33	13·25	11·32	12·35	*None*
	(4·8)	(5·8)	(5·3)	(6·0)	(4·1)	(5·6)	—

* Without parentheses transformed; within parentheses actual percentages.

Table 3. Percentage pod infection by all fungi (WB; BP; OD) and percentage healthy pods (H) as means per plot (Harvest Aug to Feb)

Treatments:	*Sprayed, no. applications* 4	8	12	*Harvest interval, weeks* 1	2	4	*Crit. diff.* 5%
WB, BP, OD							
Infection	40·63*	38·0	38·13	44·70	45·00	49·08	5·45
	(42·8)	(38·1)	(39·5)	(50·5)	(49·7)	(60·0)	—
H							
Total harvest	46·82	48·85	48·87	42·03	42·27	37·98	5·04
	(53·1)	(56·4)	(55·5)	(44·1)	(45·7)	(37·5)	—

* Without parentheses transformed; within parentheses actual percentages.

Table 4. Total number of pods harvested as means per plot

Harvest interval	4 weeks		2 weeks	1 week
	Sprayed	Unsprayed		
Diseased	87	127	122	129
Healthy	119	84	112	112
Total	206	211	234	241

For all diseased categories (*WB*, *BP* and *OD*), but excluding pods damaged by animals, all the sprayed plots were better than the fortnightly and monthly harvesting intervals, whilst the weekly harvest just fails to attain a lower significant level compared with the control plots. The more frequent spray applications were also better than the weekly harvested treatment. Significantly more healthy pods were reaped on the blitox-treated trees, 12 and 8 applications being better than all the unsprayed trees (*Table 3*). There were indications that spraying reduced the minor fungal infections as well as black pod.

In the total harvest, both diseased and healthy, there was a tendency for more pods to be reaped from those trees harvested at more frequent intervals (*Table 4*).

Treatment effects on yield

(See *Tables 5, 6, 7* and *8*.) There was no significant difference in wet bean weights per diseased pod between treatments in either of the two important diseases, excepting the anomalous low yield for witches' broom in the sprayed (4 applications) treatment compared with the control plots. Taking the mean wet bean weight per pod over all pod categories all treatments were significantly better than the controls (*Table 5*). The yield increase ranged from 13 per cent in the 2-weekly harvested treatment to 21 per cent in the most frequently sprayed plots.

Table 5. Wet bean weights in grammes per pod (Harvest Aug to Feb)

Pod category	Sprayed, no. applications			Harvest interval, weeks			Crit. diff. 5%
	4	8	12	1	2	4	
WB	13·1	14·9	19·3	16·6	16·7	23·4	7·68
BP	78·2	70·0	59·0	81·4	57·3	61·5	*None*
All diseased	30·8	27·8	28·9	37·8	37·0	36·2	*None*
H	151·2	157·5	157·8	167·4	161·5	154·8	10·55
All pods	93·8	100·3	100·3	93·8	91·4	79·6	10·35

Table 6. Wet bean weights in kilogrammes per plot of 8 trees (Harvest Aug to Feb)

Pod category	Sprayed, no. applications			Harvest interval, weeks			Crit. diff. 5%
	4	8	12	1	2	4	
WB	0·9	0·8	1·2	1·5	1·1	1·2	0·62
BP	2·2	1·3	1·0	3·3	3·0	3·5	2·03
All diseased	3·3	2·2	2·4	5·2	4·6	4·7	2·19
H	19·3	17·1	19·4	18·8	18·0	13·1	4·36
All pods	22·6	19·3	21·9	24·0	22·6	17·8	5·06

Table 7. Percentage yields in wet beans per pod from different categories taking yield from healthy pods as 100 per cent

Pod category	Sprayed, no. applications			Harvest interval, weeks		
	4	8	12	1	2	4
WB	9	9	12	10	10	15
BP	52	44	37	49	35	40
All diseased	20	18	18	23	23	23
All pods	62	63	64	56	57	51

Table 8. Calculated yields per acre of 300 trees in pounds of dry cocoa (Harvest Aug to Feb)

Category	Yields from healthy pods	% increase over untreated	Yields from all pods	% increase over untreated
Sprayed (based on 144 trees)	616	44	716	22
Frequent harvest (based on 96 trees)	604	41	768	31
Untreated (based on 48 trees)	428	—	588	—

Also as yields per plot all the treatments showed increases (*Table 6*). These were up to 35 per cent in those harvested every week. Yield from witches' broom infected pods was highest in the most frequently harvested treatment, whilst those for black pod were highest on the unsprayed trees. This latter would be expected since there had been some control of black pod by the blitox. Yields from healthy pods only were higher in all treatments when compared with the control plots.

DISCUSSION

Witches' broom

The amount of pod infection (30 per cent in the control plots) was unexpectedly high, especially since ICS 1 is not considered a highly susceptible clone (Baker and Dale, 1944; Holliday, 1954b). Vegetative infection seen during the experiment indicated that the routine removal of brooms was not being done efficiently. Spraying under these conditions is probably wasteful as far as controlling witches' broom is concerned. It is considered that pod infection could be kept below 10 per cent using the long recommended measures (Baker and Crowdy, *loc. cit.*). The object of these small-scale spraying trials in Trinidad has been to determine whether pod losses can be reduced still further after brooms have been adequately removed.

The failure, in this experiment, to reduce incidence with a proprietary copper fungicide was unexpected in view of the earlier and promising results at Non Pareil in 1952–53 (Holliday, 1954c). It seems that pod attack by *M. perniciosus* is proving less readily controllable by copper spraying than that due to *P. palmivora*. Against the former disease, protection of the very young pods is the objective and it is possible that low pressure

knapsack spraying is inefficient in ensuring coverage on young as well as on almost full-grown pods. Also since the surface area of young pods is increasing quickly applications may have to be given more frequently in the early part of the season when the crop is setting.

Because of the long incubation time of this pathogen it was not to be expected that reducing the interval between harvests would have much effect on incidence. This was so. But the significant increase in witches' broom in the weekly harvested treatment was unexpected (*Table 1*), the reason for this apparently being that if the time interval between recordings is too long field identification of the primary invader becomes uncertain. Pods with lesions of the indurated type, that is without distortion of the pod wall, are not easily identified if left long enough on the trees to become masked by a secondary fungal invader whose necrosis spreads more rapidly. Since masking would be least on the weekly harvested plots fewer witches' broom lesions would remain undetected.

Experience with harvesting had already suggested that the interval of one month usually adopted in Trinidad for recording pod yields in field experiments where disease percentages were wanted was too long. The 'other diseases' category which contained pods whose identification was uncertain was in fact least in the weekly harvested plots (*Table 2*).

Black pod

This is not the place to review work on the control of black pod, but something should be said of studies in West Africa where most of the work has been done. Early recommendations for reducing incidence of this disease in West Africa were soundly based on the fact that the fungus, initially, only penetrates the pod shell and does not damage the beans. Therefore harvesting at more frequent intervals than the customary eight weeks or longer should reduce losses and possibly incidence as well (Dade, 1926 and 1931). Much later Owen (1951) showed what might be predicted from Dade's work. This was that, whilst copper spraying might reduce the percentage black pod more when compared with frequent harvesting, it would not necessarily result in an increase in bean yield. Owen (*loc. cit.*) found that his weekly harvested treatment gave significantly more beans per pod than did the sprayed treatments.

Thorold (1953b and 1957) and Wharton (1957 and 1958) again clearly demonstrated the effectiveness of copper sprays in Nigeria and Ghana respectively. Yield increases of up to 50 per cent were found also when trees harvested weekly were compared with those harvested once a month. In Ghana, Wharton, in the season 1955–56, apparently attributed this yield increase to a reduction in the incidence of the disease in the more frequently harvested plots; and not simply to a better recovery of beans from pods already infected. On the other hand Owen's data suggest that the increased yield from more frequently picked trees was mainly due to better bean recovery from infected pods. In the experiment reported here it seems, as might be expected, that both factors are operating. That is, yield increase from trees more frequently picked is due both to lowering the amount of inoculum and to better recovery of beans from pods already attacked.

There are few data on the incidence of black pod in Trinidad. It has been usually considered, *a priori*, that the disease was only serious in the wetter months in the higher rainfall areas to the east, the drier central cocoa belt being less affected. The experiment has shown how high the infection rate can be: nearly 28 per cent over the main crop period. Further, this amount does not include probable losses of infected cherelles which would not have reached the imposed 10 cm size limit.

The spraying treatments reduced infection by 48 to 67 per cent and the harvesting treatments by 13 to 14 per cent. The highest percentage of healthy pods occurred on those plots sprayed most frequently; an increase of up to 48 per cent over the controls. The shortest intervals between harvesting both reduced the number of pods infected and increased the bean yield from such pods (*Tables 1* and *5*).

Yield

The wet bean weight per pod is probably the most satisfactory method for assessing the effects of treatment on yield. Infection by witches' broom resulted in losses of 90 per cent of wet beans per pod, which is comparable to a rate of 91 per cent given by BAKER and HOLLIDAY (1957) from River Estate, Trinidad, a lower rainfall area. As expected, yields per pod were higher in black pod infections. Taking the yield from healthy pods as 100 per cent, in those trees harvested once a week the yield from black pods was 49 per cent and from witches' broom pods 10 per cent. At a 50 per cent infection rate for both diseases, and in weekly harvesting, the bean loss due to *P. palmivora* would be 25 per cent and to *M. perniciosus* 45 per cent. The slightly higher bean weights per healthy pod shown in the weekly harvest were unforeseen. This is presumably due to less moisture loss in the mucilage, a loss increasing with the time that the ripe pod is left unpicked (*Table 5*).

The overall increased yield shown by the sprayed plots is due to reduced infection by *P. palmivora* and minor fungi. Although control of the infections was less on the frequently harvested plots, the yield increase on a plot basis was of the same order. This was because more pods were reaped (*Tables 1* and *2*) and because of the better recovery of beans from black pods in the weekly harvested treatment (*Table 5*).

The experiment suggests that general copper spraying, not normally done, would be beneficial in Trinidad. In the wetter areas on reasonably high yielding stands yield increases of up to 25 per cent could be expected. The increases from reducing the time interval between harvests would probably be similar. But, if better control of witches' broom by spraying can be achieved, fungicides are likely to increase yields over and above what can be achieved by improving and modifying husbandry. Nevertheless the results add weight to the general recommendations for more effective sanitary measures in cocoa disease control. In Trinidad better control of both witches' broom and black pod could be achieved by applying existing knowledge.

SUMMARY

An experiment in the control of cocoa (*Theobroma cacao* L.) pod diseases caused by fungi, especially witches' broom (*Marasmius perniciosus* Stahel)

and black pod (*Phytophthora palmivora* Butl.), was carried out on mature trees of a single clone in a high rainfall area in Trinidad. Knapsack type spraying with copper oxychloride (blitox) during the wet season reduced black pod by up to 67 per cent. There was no control of witches' broom but some of other, less important, fungal infections. Frequent harvesting reduced black pod by up to 41 per cent and also reduced minor fungal infections. As expected it had no effect on witches' broom incidence. Spraying increased the healthy pod harvest by up to 48 per cent and frequent harvesting by up to 22 per cent. Bean yield per pod was increased by all treatments over control plots; the highest yield was given by the most frequently sprayed plots. Crop loss, as beans per pod, was 90 per cent in witches' broom infections and 60 per cent in those caused by black pod in the control plots. The experiment indicated that yields were increased by 128 lb of dry cocoa per acre (22 per cent) on the sprayed plots, and by 180 lb (31 per cent) on those frequently harvested.

ACKNOWLEDGEMENT

The Hon. Sir Harold Robinson kindly allowed his trees at Non Pareil Estate to be used in the experiment.

(*Received November 1959*)

REFERENCES

Baker, R. E. D. and Crowdy, S. H. (1943). 'Studies in the witches' broom disease of cacao caused by *Marasmius perniciosus* Stahel'. *Mem. imp. Coll. trop. Agric., Trinidad,* Part I, No. 7, 28 pp

Baker, R. E. D. and Dale, W. T. (1944).' Witches' broom disease investigations, X—Loss of pods in ICS clones at River Estate during 1943'. *Trop. Agriculture, Trin.* **21,** 196

Baker, R. E. D. and Holliday, P. (1957). 'Witches' broom disease of cacao (*Marasmius perniciosus* Stahel)'. *Phytopath. Paper, Commonw. mycol. Inst.* No. 2, 42 pp

Dade, H. A. (1926). 'Economic significance of cocoa pod diseases and factors determining their incidence and control'. *Bull. Dep. Agric. Gold Cst,* No. 6

Dade, H. A. (1931). 'The determination of incidence of black pod disease of cocoa'. *Bull. Dep. Agric. Gold Cst,* No. 23

Dale, W. T. (1946). 'Witches' broom disease investigations, XII—Further studies on the infection of cocoa pods'. *Trop. Agriculture, Trin.* **23,** 217

Dale, W. T. (1953). 'Plant pathology; a progress report'. *Rep. Cacao Res. Trinidad, 1952,* 60

Fisher, R. A. and Yates, R. (1953). *Statistical Tables for Biological, Agricultural and Medical Research,* p 66. Oliver and Boyd: Edinburgh

Holliday, P. (1954a). 'Control of witches' broom disease of cacao in Trinidad'. *Trop. Agriculture, Trin.* **31,** 312

Holliday, P. (1954b). 'The susceptibility of some Imperial College Selections to witches' broom disease'. *Rep. Cacao Res. Trinidad, 1953,* 56

Holliday, P. (1954c). 'Spraying experiments against witches' broom disease'. *Rep. Cacao Res. Trinidad, 1953,* 64

Owen, H. (1951). 'Cocoa pod diseases in West Africa'. *Ann. appl. Biol.* **38,** 715

Thorold, C. A. (1953a). 'Observations on fungicide control of witches' broom, black pod and pink disease of *Theobroma cacao* L.'. *Ann. appl. Biol.* **40,** 362

Thorold, C. A. (1953b). 'The control of black pod disease of cocoa in the western region of Nigeria'. *Report of the Cocoa Conference, London, 1953,* 1

Thorold, C. A. (1957). 'Black pod disease of cocoa'. *Rep. Dep. agric. Res. Nigeria 1954–55,* 14

Wharton, A. L. (1957). 'Black pod disease'. *Rep. W. Afr. Cocoa Res. Inst. 1955–56,* 42

Wharton, A. L. (1958). *Rep. W. Afr. Cocoa Res. Inst. 1956–57,* 32

Note.—It has recently been reported that low volume spraying of cocoa with 'perenox' (cuprous oxide) in Trinidad has indicated yield increases of 200 lb dry cocoa per acre:
Anon. (1958). *Adm. Rep. Dir. Agric. Trin. Tob. 1956*

Book Reviews

PRACTICAL BOTANY FOR THE TROPICS

W. O. Howarth and L. G. G. Warne. University of London Press: London, 1959. 238 *pp.* (illus.) 15*s*

This book describes and explains the practical work of an elementary course in Botany. A selection of tropical plants is suggested for working examples. There is no doubt that both teacher and student of botany in the tropics will find that this is a very useful book.

However, it has limitations as a working practical manual. The authors often go into considerable detail and deal with some subjects as thoroughly as a good textbook. This is surely neither necessary, nor desirable, in a practical manual. Indeed, as the authors themselves point out in their introduction, a student should attend a practical class with some pre-knowledge of its subject matter, gained from attendance at lectures and reference to a suitable textbook. It is clear that, with this background, the student can devote the maximum time available to his practical work, i.e. observing, recording and interpreting, and spend a minimum of time checking over procedural instructions and explanations.

The value of some of the twelve plates is questionable. For example plates II A and B show longitudinal and transverse sections of an onion bulb. Surely the student is going to see everything these plates show more clearly in his own sections of fresh material. Again, Plate VIII shows a simple compound microscope, parts unlabelled. What use is this in a practical manual? An illustration with the various parts labelled would certainly be instructive. At least half of the plates add nothing of value to the book and would be better omitted. They might be replaced by more line drawings which, if correctly labelled and clearly diagrammatic, often illustrate a point concisely and effectively, without doing all the work for the student. There is a notable lack of such illustrations, except in the physiology chapters (e.g. Chapters 17 and 20).

In the chapters dealing with stem, root and leaf anatomy, there was an opportunity of showing the student how to prepare a good low power tissue diagram, and high power drawings of the cells which make up those tissues. The authors have failed to make the most of this opportunity. It would have been preferable to enlarge Fig. 10, thereby showing the detail included in both Figs. 10 and 11. Referring to detailed drawings under high power the authors write (page 86), 'The drawing is built up cell by cell, each cell being drawn correctly for shape and size, thickness of wall, contents, and put into the same position in the drawings as it occupies in the section. Such a drawing is illustrated alongside the photomicrograph (Plate V) in Fig. 13'. In fact, in Fig. 13, no cell contents are shown, the wall thickness is inadequately represented, there is no scale, and I would strongly advise a student against attempting to draw so many cells under high power.

There are twenty three chapters devoted to Angiosperm morphology, reproduction, anatomy and physiology and the remaining five chapters cover Algae, Fungi, Bryophyta, Pteridophyta and Gymnosperms. How *Fucus* finds a place within the tropics is not clear, but *Sargassum* is included as an alternative.

Appendix I, detailing the make-up of various solutions and Appendix III, ' Useful Molecular Weights ', should both prove useful.

There is a wealth of instructive information between the covers of this book. It will find a place in botany teaching laboratories throughout the tropics, even if that place is not on the bench in front of the student.—W.D.R.

THE MANURING OF COFFEE, COCOA, TEA AND TOBACCO

F. J. E. VAN DIERENDONCK. Centre d'Etude de l'Azote: Geneva, 1959. 205 *pp.* (illus.)

A reviewer is perhaps a little suspicious at first of a publication that is as beautifully produced as this one is, with its glossy covers, excellent paper, coloured frontispiece and plates and numerous photographs. It is most pleasing to record, therefore, that the contents are of a similar high standard.

Relevant information on the four crops has been well summarized and definitive conclusions drawn as far as possible. The influence of other factors, more especially shade, on the effect of fertilizer application has been clearly explained. The text is supported by a bibliography which is not exhaustive but entirely adequate and the book could be read with profit not only by the research worker but by any progressive grower of these four important crops.—D.B.M.

CO-OPERATIVE ORGANISATION IN TROPICAL COUNTRIES, 1945-55

S. GORST. Blackwell: Oxford, 1959. *xiii*+343 *pp.* 25*s*

This handbook gives a review of co-operative development in Non-Self-Governing countries under United Kingdom Administration. The first part presents a review country by country grouped into seven global units; the second part presents observations and conclusions from the foregoing review. The work covers the whole field of co-operation and is not concerned particularly with agricultural co-operatives. For instance in the useful Summary of Conclusions only 6 paragraphs out of 38 deal specifically with agriculture.

The very convenient tabular presentation of the broad facts at the beginning of Part II shows the rapid development of the movement in these ten years, from one quarter to one and a quarter million members, from a total turnover of £3 to £86 million, capital ' owned ' by members from £2¾ to £27 million. Credit Societies are still the most common type of co-operative in these territories, but marketing societies which have increased from 418 to 3 797, now almost equal them in numbers and

exceed them by almost five times in turnover. Nevertheless, as the author points out, the co-operative movement has as yet made little impact on the total populations and the overall economics of most of the countries studied. The exception is the Gilbert and Ellice Islands where every member of the population is associated with one or more of the 41 co-operatives there. The great expansion in the last decade may possibly be the beginning of even greater things.

The author has obviously carried out thorough research on a mass of what must have been very inconsistent data. She has shown herself competent and generally impartial though on a few occasions her dedication to this movement does tend to elbow aside the facts she is reviewing. How can you say that traffickers exploit growers of perishables when co-operatives and other organizations have proved unsuccessful in marketing these difficult products? Why imply that Governments should as a normal obligation make finance available (on easy terms presumably) to co-operatives? However, these are minor blemishes that are symptoms of what seems to be an occupational disease of writers on co-operation.—A.L.J.

THE APPLICATION OF GENETICS TO COTTON IMPROVEMENT

SIR JOSEPH HUTCHINSON. Cambridge University Press in association with the Empire Cotton Growing Corporation: London, 1959. *viii*+86 *pp.* 15*s*

This lucid and stimulating book is based on lectures delivered by Sir JOSEPH HUTCHINSON at North Carolina State College in 1954, together with more recent material from the work in progress at Namulonge.

As stated on the dust cover ' Sir JOSEPH reviews the range of the genus *Gossypium* and the place in it of the four species which constitute the cotton of commerce. He traces the historical development of these species, in both the Old and the New Worlds, from the coarse, short perennials grown over 4 000 years ago to the very fine, long-fibred annuals of today. He describes the development of strains resistant to the jassid pest and to bacterial blight and other diseases, by hybridization of races from different parts of the world. Breeding techniques are discussed in the light of recent work in Africa and the prospects for future development assessed . . . This survey will be of interest to geneticists and plant physiologists generally, as well as to those who have a particular concern with cotton '. I would go further and say that the book should be of interest to all tropical agriculturists and botanists. Workers in temperate countries could derive benefit from it and it will provide them with food for thought.

On the question of nomenclature, PROKHANOV (1959) considers that the correct name of *Gossypium barbadense* L. is *G. peruvianum* Cav., as LINNAEUS's type specimen grown at Uppsala was *G. arboreum* L. Thus *G. barbadense* becomes a synonym for *G. arboreum* and the oldest legitimate name for the Sea Island cottons is then *G. peruvianum* Cav.

I find it difficult to accept Sir JOSEPH's hypothesis that the diploid *G. herbaceum*, which is only truly wild in southern Africa, was taken by man across the Pacific to northwestern Peru at least 4 500 years ago, where it

was grown and crossed with the wild, lintless, diploid *G. raimondii*, giving rise to the allopolyploid *G. peruvianum*. Fragments of fishing net, line and fabric made of cotton have been found in excavations at Huaca Prieta in north Peru on a site occupied by people who were primarily fisher folk, but who practised a primitive agriculture from the earliest times. Cotton seeds, dated 2 400 B.C., found in the midden can be assigned to *G. peruvianum* with some degree of confidence and Sir JOSEPH says: '*there is nothing to suggest the presence of an Asiatic cotton*' (the italics are mine). The technique of making twine was fairly good, but that of textile manufacture was very poor and 'textile making tools were extremely primitive or absent'. No mention is made in the book under review of the spinning instruments found in desert graves in pre-Inca Peru where 'an ancient civilization was located which used cotton as its basic textile and spun and wove it with instruments that differed in no essential particular from those used in Asia', an argument used by HUTCHINSON *et al.* (1947) in support of their hypothesis at that time.

The cytogenetical evidence of the origin of the New World cottons appears to be beyond doubt; it is the way in which the parent species were brought together that I question.

Apart from the difficulties of a trans-Pacific crossing by man at this early date, it is even more surprising that these early voyagers do not seem to have taken any food crops with them, as none of the food crops grown at Huaca Prieta are of Old World origin. In fact, the only crops common to the Old and New Worlds prior to 1492 were the common gourd (*Lagenaria siceraria*), sweet potato and coconut. *Lagenaria* still presents a problem, but, since it floats, it could have been distributed by sea. Although the sweet potato is usually considered to have originated in tropical America, this is not necessarily the case. Some authorities consider that it originated in tropical Africa. However, the cultigen is thought to have been derived from the wild species *Ipomoea tiliacea*, which is tuberous rooted and is widespread in tropical America, west tropical Africa and from eastern Malaysia to New Guinea. Thus *I. batatas* could have been developed independently in several regions and then been taken later by the Maoris to New Zealand in pre-Columbian days. Coconuts were discovered by the Spaniards growing on the west coast of Panama, but they cannot have been there very long, otherwise one would expect that they would have been taken over the narrow isthmus and become established on the Atlantic coast prior to Columbus. As MERRILL (1954) points out, there are 1 800 or more cultivated species which were not common to both hemispheres until after 1492. This provides a cogent argument against many of the diffusionist theories put forward by several authorities, such as HEYERDAHL and SAUER, as well as Sir JOSEPH's hypothesis of the origin of the New World cottons.

A further difficulty is that only seeds of *G. peruvianum* were found in the excavation of the Huaca Prieta midden (p 27). If these fishermen had taken *G. herbaceum* with them and grown it, when it then crossed with *G. raimondii*, I should have expected seeds or remains of *G. herbaceum* to have been found in the oldest part of the midden. Furthermore, the Old World cottons have not been found wild nor commensal with man in Peru or elsewhere in the New World.

G. tomentosum, a New World linted cotton which is wild and endemic in Hawaii, also presents a difficult problem. Sir JOSEPH considers that it originated from the same polyploidy as *G. peruvianum*. Thus it must have been taken by man in the reverse direction across the Pacific. The rapid rate of differentiation of the cultivated cottons is due to the influence of man. *G. tomentosum* does not have this advantage, as it has not been domesticated, has a very limited distribution and no other species of *Gossypium* are found near it. Thus it is difficult to believe that this species could have become so differentiated in the time postulated, as was also doubted by MANGELSDORF and OLIVER (1951).

STEBBINS (1950 and 1959) has postulated that *G. herbaceum* crossed over the Siberian–Alaskan land bridge in Tertiary times, with subsequent hybridization and amphiploidy in northern America, followed by the extinction of *G. herbaceum* in northern America and Asia, and the survival of *G. raimondii* in its present southern refuge.

As has already been suggested by MERRILL (1954), I think that a more logical explanation of the origin and spread of both the ancient, relict, lintless species of *Gossypium* and the early 'cultivated' cottons is via Antarctica, probably in Tertiary times, when this vast land area carried in places a sub-tropical flora, as is shown by the palaeobotanical records. It is possible that *G. herbaceum*, in which the mutation for lint had occurred, *G. raimondii*, and their allopolyploid hybrid *G. peruvianum* could have been developed in Antarctica and then retreated northwards into the respective continents as glaciation advanced. If MERRILL is correct in his belief 'that there are in the Pacific Islands certain floristic elements that reached these islands from ancient Antarctica', this would explain the present position of *G. tomentosum*. If the genus and species originated elsewhere, then Antarctica could provide the route by which they spread. There are a number of genera of plants in South America, South Africa and Australia which could also have been spread in this way.

In this connection it is of interest to record that DARWIN (quoted by SEWARD, 1931) wrote to his friend HOOKER 'there must have existed a Tertiary Antarctic continent from which various forms radiated to southern extremities of our present continents'. SKOTTSBERG, quoted by GOOD (1953) states 'the disappearance of the Tertiary Antarctica flora during the ice ages is of fundamental importance and has been greatly underestimated by plant geographers. No catastrophe of such dimensions and of such consequences has ever befallen the Tertiary flora of the northern hemisphere'.

Sir JOSEPH considers that both the northern Polar and Antarctica routes are improbable, as they do not offer a frost-free desert route for the migration of cotton. However, I would have expected arid or semi-arid areas to have occurred in parts of Antarctica, as is the case with other large land masses, although I have no evidence to support this at present. On the palaeobotanical evidence and the existence of coal deposits, there must have been times when parts of Antarctica were free of frost.

Until further evidence is forthcoming only surmise is possible. The possibility of cotton originating in WEGENER's original land mass, the species being separated as the continents drifted, should not be lost sight of, nor should HARLAND's (1939) theory of a trans-Pacific land bridge.

The problem of the origin and spread of the cultivated cottons is an intriguing one, but there is much in Sir JOSEPH's book besides this. Once again, a short book by Sir JOSEPH has stimulated me to write a very long review. —J.W.P.

REFERENCES

GOOD, R. (1953). *The Geography of the Flowering Plants.* 2nd ed. Longmans Green: London

HARLAND, S. C. (1939). *The Genetics of Cotton.* Cape: London

HUTCHINSON, J. B., SILOW, R. A. and STEPHENS, S. G. (1947). *The Evolution of Gossypium and the Differentiation of the Cultivated Cottons.* Oxford University Press: London

MANGELSDORF, P. C. and OLIVER, D. L. (1951). 'Whence Came Maize to Asia?' *Bot. Mus. Leafl. Harv.* **14,** 263–291

MERRILL, E. D. (1954). *The Botany of Cook's Voyages . . .* Chronica Botanica: Waltham, Mass.

PROKHANOV, Y. (1959). 'What is *Gossypium barbadense* Linnaeus?' *Taxon,* **8,** 41–46

SEWARD, A. C. (1931). *Plant Life through the Ages,* p 463. Cambridge University Press: London

STEBBINS, G. L. (1950). *Variation and Evolution in Plants.* Columbia University Press: New York

STEBBINS, G. L. (1959). In *Vistas in Botany,* pp 258–290. Pergamon: London

FLORA ZAMBESIACA

Mozambique, Federation of Rhodesia and Nyasaland, Bechuanaland Protectorate

Vol. I, Part I

Edited by A. W. EXELL and H. WILD. Crown Agents for Overseas Governments and Administrations: London, 1960. 336 *pp.* (illus.) 25*s*

The appearance of a new flora for one of the major regions of the world is always an exciting event, particularly when no previous flora exists for that area. With the publication of Volume I, Part I of the *Flora Zambesiaca,* work is now in progress on the floras of most of the major regions of tropical Africa. The other floras in the process of publication, or already published, include ANDREW's *The Flowering Plants of the Anglo-Egyptian Sudan* (1950–56), EXELL and MENDONÇA's *Conspectus Florae Angolensis* (1937–), *Flore du Congo Belge et du Ruanda-Urundi* (1948–) published by the Institut National pour l'Etude Agronomique du Congo Belge, HUTCHINSON and DALZIEL's *Flora of West Tropical Africa* (1927–36), 2nd edition revised by KEAY (1954–) and TURRILL and MILNE-REDHEAD's *Flora of Tropical East Africa* (1952–).

The new flora covers an area of 1 069 000 square miles between latitudes 8° 10′ and 26° 50′ S and longitudes 20° and 40° 50′ E, which falls mainly within the drainage basin of the Zambesi River and includes the Federation of Rhodesia and Nyasaland, Mozambique and Bechuanaland Protectorate. It is a splendid example of international cooperation between the governments and botanical institutions of the territories concerned. Much of the work for the flora is being done at the British Museum and Kew. It is financed jointly by the governments of the territories concerned and the United Kingdom. The project was initiated in 1955.

The sequence of families being followed is that of BENTHAM and HOOKER and the present volume takes us from the Gymnospermae to Polygalaceae, a total of 20 families. It includes a key to all the families of flowering plants occurring in the region which has been prepared by Mr DANDY, an illustrated

glossary of botanical terms and a history of botanical collecting in the area. The principal authors of the present part are Messrs EXELL, ROBSON and WILD, while specialists have contributed on their particular families, including Drs CUFODONTIS and TROUPIN.

Each territory is divided into areas as shown on the map at the back of the volume and one specimen is usually cited for each of the divisions in which the species occurs. The excellent, full-page illustrations by Misses RIPLEY and DALBY add greatly to the value of the flora, and an illustration is usually given of at least one species in each genus. The distinguished managing committee of the *Flora Zambesiaca* and everybody connected with this admirable new venture are to be congratulated. It has long been needed. Not only will it be of the greatest value to agriculturists and foresters working in the area, but it should ' stimulate local interest in the botany of the region by providing the inhabitants as a whole with the means of recognizing the plants which grow around them '. We look forward eagerly to the publication of further parts of this new flora.—J.W.P.

AGRICULTURAL INSECTS OF EAST AFRICA

Compiled by R. H. LEPELLEY. East Africa High Commission: Nairobi, 1959. *x*+307 *pp.* 42*s*

The sub-title fully describes the contents of this publication: ' A list of East African plant feeding insects and mites, with their host plants, their parasites and predators, giving distribution by territories and references to the literature, together with lists of stored products insects and introduced insects, mainly covering the period 1908 to 1956 '.—M.E.M.P.

WEST AFRICAN COTTON RESEARCH CONFERENCE, 18 TO 23 NOVEMBER, 1957

Ministry of Agriculture: Samaru, Zaria, N. Nigeria, 1959. *v*+209 *pp.* (illus.) 15*s*

The main points made in discussions during the various sessions dealing with agronomy; breeding and selection; entomology; seed multiplication and distribution; pathology; legislation, grading and marketing; and plant environment, are followed by 33 appendices containing the full texts of papers presented at this conference.—M.E.M.P.

SOILS OF THE SUGAR BELT
Part II: Natal South Coast

B. E. BEATER. Oxford University Press: London, 1959. 77 *pp.* (illus.) 35*s*

This is the second of three reports on the soil groups under sugar-cane in Natal. The area concerned extends along the coast for about 90 miles south of Durban and intermittently farther on as far as latitude 31° 01′, the most southerly point in the world where sugar-cane is grown commercially. The first section gives detailed records of temperature,

rainfall and production of sugar-cane in this area. Yields are compared with those from the north coast area and the causes are discussed for the lower yields on the south coast.

The topography of the area is described as gently undulating except in the neighbourhood of the rivers where the land becomes steep. The geology of the area, described in some detail, is very varied and ranges from Pleistocene sands through various sedimentary formations and granites to older rocks of schists, amphibolite and quartzite. Soils derived from granite cover more than 40 per cent of the area in contrast to the north coast where the predominant soil group is Table Mountain sandstone.

The section on soils is not a comprehensive one from the pedologist's point of view. It begins by explaining what a soil profile is and goes on to give a brief description of the soils derived from the various geological formations. As the writer himself states, the classification is based on the nature of the underlying rock alone and thus no account is taken of the other factors affecting soil formation. Even though the area is only gently undulating, differences in soils resulting from topography alone could be expected. The effect of climate is noted when very similar soils are developed over widely different parent materials in the mist belt and conversely when the same parent material, e.g. Table Mountain sandstone, gives different soils in the mist belt and non-mist belt. The relative fertility of groups and sub-groups is examined by carrying out a series of analyses, including available phosphate, potassium, lime, magnesium and exchangeable bases on uncultivated soils.

A detailed description of the mineralogy of the rocks and corresponding soils is given and this is the most comprehensive section of the report, the excellent photographs of rock and soil sections being an unusual feature for a soil report.

The multi-coloured map, of a rather awkward size, is very well produced and is on a scale of 1 in.=1 mile. It represents a field by field survey of 198 estates. The method of approach to soil classification and mapping means, however, that the map is of limited application other than for the growing of sugar-cane. This is, of course, the primary purpose of the work but it seems a pity, in view of the work involved, that a more objective report and map were not produced.—J.K.C.

MIST PROPAGATION OF CUTTINGS

P. Rowe-Dutton. *Digest No. 2.* Commonwealth Bureau of Horticulture and Plantation Crops. Commonwealth Agricultural Bureaux: Farnham Royal, Bucks., 1959. *iv*+135 *pp.* (illus.) 10*s*

The rooting of cuttings has been a recognized technique of horticulturists and nurserymen for centuries. It is only comparatively recently, however, that much attention has been paid to improving techniques and applying scientific skills to the ' green fingers ' of the gardener.

One of the most important modern advances has, of course, been the use of synthetic hormones to increase the speed of rooting. This booklet covers another aspect, the maintenance of turgidity in the cutting while it is rooting. The traditional methods try to secure this by providing

conditions under which transpiration is kept at a minimum. The mist techniques are more positive and aim at maintaining a film of water over the cutting and its leaves.

Although very successful rooting may be obtained from continuous mist, i.e. open spray beds with low delivery nozzles, there are a number of developments for intermittent misting. The various devices are well described and illustrated including the various types of 'electronic leaf'. This development lends itself to 'gadgetry'—increasingly ingenious and complicated controls—and although a breakdown may not be serious where expert attention is available it could be disastrous otherwise.

The practical details of glasshouse construction and adaptation to mist propagation, use of plastic structures, types of nozzles, rooting media, etc., are summarized and there is a select bibliography of some 160 references. An appendix gives the results obtained with mist propagation for a wide range of economic and ornamental species.

This digest should prove most valuable for anyone interested in vegetative propagation by cuttings, not only from the viewpoint of the practical nurseryman but also for the research worker concerned with improving techniques for rooting cuttings.—D.B.M.

GRAZING CONTROL

Law and Regulations in Various Countries for the Control of Grazing to Prevent Injury to Grasslands

Compiled by A. G. G. Hill. *Mimeographed Publication No. 2/1959.* Commonwealth Bureau of Pastures and Field Crops: Commonwealth Agricultural Bureaux, Farnham Royal, Bucks., 1959. 27 *pp.* 7*s.* 6*d*

This publication lists concisely information concerning grazing control legislation obtained by the Bureau from over sixty countries. It is perhaps a pity that the compiler did not conclude with some general discussion about the points arising from this interesting collection of data.

The publication draws attention to the great lack of adequate control measures in most countries which are confronted with major problems of grazing abuse. Thus it is significant that the nomadic pastoral areas in the Northern Region, Nigeria, Somaliland and the Sudan have no existing control regulations and no tradition of planned control of grazing by chiefs.

The regulations adopted by Basutoland stand out in marked contrast to those of other countries as an example of what can be done where control measures enjoy the general consent of the peoples affected by such measures. The combination of rules and regulations concerning the control of fire on the one hand and the control of grazing on the other is recommended and should be more widely adopted.

This publication is of value, as the compiler suggests in the introduction, to all those who are concerned with drafting or enforcing grazing control legislation. It will also be welcomed by those who attempt the difficult task of teaching courses in tropical grassland husbandry.—P.N.W.

THE STATE OF FOOD AND AGRICULTURE 1959

United Nations Food and Agriculture Organisation: Rome; Her Majesty's Stationery Office: London, 1959. *ix*+197 *pp.* (illus.) 10*s*

The Food and Agriculture Organisation of the United Nations continues its authoritative and up-to-the-minute reviews of world agriculture in this volume. It is, in common with its predecessors, of particular interest to the tropical agriculturist in giving him a comprehensive review of the products he is interested in, no doubt due to the sympathy and interest F.A.O. has always displayed in 'underdeveloped' countries.

The present report indicates that this interest is still growing. World agricultural production in general terms has recovered from the effects of the recession in 1957 and 1958 which affected raw materials production more severely than food. In general terms also agricultural production is expanding as rapidly as world population, indeed stocks of agricultural products (mainly in the U.S.A.) increased by about 10 per cent. It is, however, the underdeveloped countries that present the main problem. Although rates of population increase appear to be slowing somewhat, they are still greater than in other countries and are being maintained in Latin America. Agricultural production per head of this expanding population is increasing slowly if at all and is rarely much more than it was before 1939. The notable problem areas in this respect are those growing rice in southeast Asia, parts of Africa and Latin America; the earnings from export in Oceania have declined by no less than 23 per cent. The F.A.O. has still a vast and vital mission to these countries.

It is probably superfluous again to congratulate the compilers of this report on the general high standard of presentation. The report is not only uniquely comprehensive and astonishingly up-to-date but cleverly combines a narrative of the world's changes with a volume of statistical information.—A.L.J.

F.A.O. Marketing Guides

United Nations Food and Agriculture Organisation: Rome; Her Majesty's Stationery Office: London

No. 1. Marketing problems and improvement programs

By J. C. Abbott. 1958. *xiii*+260 *pp.* (illus.) 12*s* 6*d*

No. 2. Marketing fruit and vegetables

Prepared on the basis of advice submitted by a team of experts in the Netherlands. 1957. *xii*+205 *pp.* (illus.) 10*s*

'The purpose of this guide is to promote a better understanding of marketing, to bring about a wider appreciation of its significance and to indicate ways in which existing marketing practices may be improved'. So runs the first sentence of the first issue of a new F.A.O. series. It is refreshing to be introduced to a book in such clear and definitive terms. It is salutary too for the agronomist to be made to reconsider the relative importance of his part in the whole sphere of agriculture, by this most erudite and exhaustive presentation of the facts of marketing.

Following an introductory chapter, in which we see that the term 'Marketing' has broadened in recent years to include 'business activities

involved in the flow of goods and services from producer to consumer ', are three chapters (really sections) comprising the body of the book and elaborating the three broad aspects quoted above. Thus the first discusses marketing in terms of its functions, i.e. assembly, preparation and distribution, of its various services, including financial, its organization into various types of market from simple producer–consumer to more elaborate central wholesale, and finally touches briefly on price mechanisms. The central section deals at length with characteristic marketing problems and the final with means of improvement in which cooperatives, boards and government action are described. The part played by the F.A.O. through its Technical Assistance programme is quietly mentioned at the end.

Details and examples of a very wide range of agricultural commodities are presented from countries throughout the world with emphasis on tropical and underdeveloped areas, and coverage of plantation, indigenous, export and locally consumed products.

This study has over forty good photographic illustrations, suitably chosen, which add to the reader's interest.

The author's style is authoritative yet agreeable to read. He has no doubt been assisted by reports from resident F.A.O. marketing experts which have added authenticity and liveliness to the text.

The printing is clear but narrow margins make the lines somewhat tiresomely long. The paper binding is the poorest feature and is quite inadequate for a book of this calibre.

This volume in particular and probably the series as a whole will be of considerable value to a wide audience including students and those for whom it is primarily intended, namely, marketing advisers, organizations and those generally ' in the trade '.

The second of the series duplicates to some extent general principles concerning producer–consumer transfer discussed in the first. Its declared purpose is to ' stimulate and aid programmes to improve the marketing of fruit and vegetables rather than to present specific data '. This is the only approach possible in a volume of reasonable size dealing with a subject, the conditions of which vary so widely from country to country. More attention is paid to temperate and sub-tropical conditions, justifiably so in view of the greater development of transportation and its associated problems in those regions, although the tropics are by no means neglected.

Packaging and storage receive detailed treatment. Under ' sales methods ' are discussed the three general kinds of market namely, grower's, wholesale and retail. Wholesale markets, and their necessary subsidiary farmers' assembly markets, are considered in a separate chapter. As an example of the successful development of wholesale marketing the Hong Kong Scheme is noted and ' vital factors in its success have been the integrity and experience of its administrators and government moral support '.

There is a wealth of specialized detail in this book including in the appendices a sectional plan of a refrigerated railcar.

This publication has some forty-six photographic illustrations, mostly well chosen and reproduced, and will be of considerable value in a necessarily general way to marketing officers, including government administrators, in underdeveloped areas.—R.H.F.

Recent Publications

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

Memoirs—Economic Series No. 2: Peasant Farming, 1*s*; No. 3: Readings in Small Scale Farming, 5*s*; No. 4: Clip-Card Accounting on the Farm, 8*s* 4*d*

A Notebook of Tropical Agriculture. 6th ed. rev. and enl. 1957. 12*s* 6*d*

THE REGIONAL RESEARCH CENTRE OF THE BRITISH CARIBBEAN

Reports on Cacao Research—1945–51, 25*s*; 1952, 8*s*; 1953, 10*s* 6*d*; 1954, 12*s* 6*d*; 1955–56, 15*s*

Reprints are available, at varying prices, of articles in these reports, including the Colour-Illustrated Guide to the Diagnosis of Mineral Deficiencies in Cacao, 5*s* plus postage

Soil and Land-Use Surveys (with maps)—

No. 1 Jamaica. Parish of St Catherine 1958, 20*s*

No. 2 British Guiana. The Rupununi Savannas 1958, 15*s*

No. 3 St Vincent. 1958, 25*s*

No. 4 Jamaica. Parish of St Andrew 1959, 12*s* 6*d*

No. 5 British Guiana. The Mahdia Valley, The Bartica Triangle, The Kamarang and Kukui Valleys, A Part of the Upper Mazaruni Valley 1959, 14*s*

No. 6 British Guiana. The Rupununi Savannas (continued). The Intermediate Savannas. General Remarks. 1959, 15*s*

No. 7 Jamaica. Parish of Clarendon 1959, 20*s*

No. 8 Jamaica. Parish of St James 1959, 12*s* 6*d*

These and earlier publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad

---

The following books written by members of the staff have recently been published:

Insect Life in the Tropics, by T. W. Kirkpatrick. Longmans, Green: London. 35*s*

Bananas, by N. W. Simmonds. Longmans, Green: London. 45*s*

CONTROL OF THE PLANT ENVIRONMENT

Proceedings of the Fourth Easter School in Agricultural Science, Nottingham, 1957

Editor: J. P. HUDSON

Control of various factors of the plant environment offers a powerful new research tool for the study of growth and yield. This approach offers attractive opportunities in fields of research ranging from fundamental aspects of plant physiology and genetics, to applications of immediate importance in plant breeding, agriculture and horticulture.

The Fourth Easter School was devoted to the "Use of Controlled Environments in Crop Experimentation". The wide interest in the field was shown by the attendance of nearly two hundred scientists, physicists, chemists, engineers, biologists, agronomists, agriculturalists, horticulturalists—all with a common interest in environmental control, and all contributing to a vigorous exchange of views between the various disciplines. Special attention was given to relatively inexpensive ways of controlling the plant environment for experimental work. Price 42s.

GROWTH OF LEAVES

Proceedings of the Third Easter School in Agricultural Science, Nottingham, 1956

Editor: F. L. MILTHORPE

All aspects of agricultural production are intimately associated with the growth of leaves, and the yield ultimately depends on the rate of addition of dry matter per unit area of land, i.e. on the efficiency of the photosynthetic processes and on the extent of the photosynthetic surface.

Agricultural writings, however, reveal much confusion as to the relevant importance of these two components of energy production with, consequently, much misdirected effort in plant breeding, fertilizer and other agronomic programmes. The 1956 School provided a forum for discussion among specialists in leaf growth. Research workers and honours students in botany, agriculture and horticulture will find much of interest in these papers. Constant reference has been made to source material and, with diligent use, this volume will assist the reader to obtain a full understanding of leaf growth. Price 40s.

QUANTITATIVE PLANT ECOLOGY

By P. GREIG-SMITH, M.A.
University College of North Wales

The growing awareness among ecologists of the need to place their science on a more exact basis is changing the emphasis from extensive work on vegetation to intensive work on selected aspects and, consequently, more precise methods of examination are necessary.

The need for improved techniques is made more urgent by the rapid depletion of natural vegetation and the realization that advances in many branches of agriculture and forestry depend upon answers to ecological questions.

The author makes an assessment of the practical potentialities of various methods and techniques, and provides guidance on the most profitable means of handling data as well as a broad survey of the quantitative approach to plant ecology.

"A useful and timely book . . . thoughtful and stimulating."—*Nature.*

"This is an excellent introduction to a subject which is at present in a state of very rapid development. The successive chapters deal with (1) the quantitative description of vegetation, (2) sampling and comparison, (3) the pattern of vegetation, (4) the association between species, (5) the correlation of vegetation with habitat conditions, (6) plant communities, and lastly (7) the quantitative approach to plant ecology, this latter being a more general and speculative approach to the whole subject. The discussion on pattern of vegetation is particularly good, and should be most helpful to anyone who has to interpret the frequency distribution of species of plants in random samples.

"The book covers a wide field, in a clear and interesting manner. It provides a good array of facts and stimulates the reader to think. Strongly recommended to all biologists with a leaning towards statistical methods."—*Journal of Ecology.*

". . . fills a void in ecological methodology . . . concise and interestingly written . . . will be a valuable addition to the library of anyone interested in ecological relationships in the study of vegetation."

—*Agricultural Institute Review*

To: BUTTERWORTH & CO. (PUBLISHERS) LTD.
Publicity Dept., 4–5 Bell Yard, London, W.C.2

Please send me full information on:

- ☐ CONTROL OF THE PLANT ENVIRONMENT, 42s.
- ☐ THE GROWTH OF LEAVES, 40s.
- ☐ QUANTITATIVE PLANT ECOLOGY, 30s.

TA.6.60

NAME _____

ADDRESS _____

This is a Ship

—the AMAKURA, one of the BOOKER LINE steamers which provide the only scheduled direct service from Liverpool to British Guiana.

She is a cargo liner carrying upwards of 3,000 tons of freight; not a big ship by modern standards, but of considerable size in comparison with the 200-ton brig "Elizabeth" which was put into service on the same run by Josias Booker in 1835.

In a changing world, the purposes of this run have remained in essence unchanged—to take to a far-off country the infinite variety of goods required to feed, clothe and serve her people and to develop new lands: and to bring back the fruits of their endeavours — principally sugar — upon which they and the country's economy depend.

The ships of the Booker Line are an essential link in the chain of Booker activities: yet despite the quality of the ships themselves, the radar and all the modern devices they are equipped with, it is upon the people who man and operate them, upon their inherent seamanship and knowledge of shipping, that the Line will always depend. They are a vital element among the 30,000 men and women employed in the Booker Group of Companies throughout the Commonwealth.

BOOKER BROTHERS, McCONNELL & CO., LTD.
Bucklersbury House, 83, Cannon Street, London, E.C.4.

PUBLISHED QUARTERLY BY BUTTERWORTHS PUBLICATIONS LTD., 88 KINGSWAY, LONDON, W.C.2. PRINTED IN GREAT BRITAIN BY R. J. ACFORD LTD., CHICHESTER, SUSSEX. ANNUAL SUBSCRIPTION INCLUDING POSTAGE—IN U.K. £2.; IN U.S.A. $5.60. ALL RIGHTS RESERVED.